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THE AMERICAN GEOGRAPHICAL SOCIETY OF NEW YORK

GUIDEBOOK

FOR THE TRANSCONTINENTAL EXCURSION OF 1912

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PREFACE

THE attempt is made in the following pages to present a concise explanatory account of the larger physiographic provinces of the United States which are to be traversed by the Transcontinental Excursion of 1912, and a more detailed statement of the local features seen along the route of the Excursion in their relation to the provinces in which they belong. The treatment of different parts of our route is unavoidably uneven, partly from lack of material, but more from lack of time available for the work of compilation. If greater emphasis is given to physiographic than to ontographic factors, this is not due to any want of respect for the importance of the second, but simply to the much greater abundance of published material regarding the first.

A number of the specialists whose studies are here cited or who have directly contributed to the preparation of this guidebook will be members of the Excursion for longer or shorter periods. Many details, necessarily omitted here, will be presented orally on the ground by experts well qualified to speak upon them.

W. M. D.

Transcontinental Excursion of 1912

PART I. THE PHYSIOGRAPHIC PROVINCES OF THE UNITED STATES

THE EASTERN UNITED STATES

The Four Belts of the Eastern United States. — The eastern part of the United States may be divided into four physiographic belts, trending northeast-southwest. 1. The Atlantic coastal plain, bordering the sea and consisting for the most part of imperfectly consolidated strata dipping gently southeast, partly stripped from their original inland extension and more or less elaborately dissected. The plain has, in consequence of a modern depression, been invaded by the sea along its northern part, and thus reduced in breadth or completely submerged. 2. The older or crystalline Appalachian belt, consisting of greatly disordered crystalline rocks, usually appearing as an uplifted peneplain surmounted by subdued monadnocks and maturely dissected by numerous valleys; this belt served as the oldland to the Atlantic coastal plain. 3. The newer or folded Appalachian belt, consisting of a heavy series of stratified formations of varying resistance and of folded structure, which like the crystalline belt has been at least once reduced to old age since the folding, and which now, after renewed regional elevation, presents the resistant strata in long, even-crested ridges, while the weaker strata are reduced to subsequent lowlands with well-adjusted drainage. 4. The Appalachian plateau, consisting of

the same stratified formations as the folded belt, but here lying nearly horizontal and elaborately dissected by insequent streams. The plateau gradually descends to the northwest and passes into the drift-covered prairie plains of the upper Mississippi basin.

The four belts vary greatly along their length. Each one may now be reviewed in more detail.

The Atlantic Coastal Plain. — The inner part of the Atlantic coastal plain appears to have passed through one cycle of

FIG. 1. A Branch of Chesapeake Bay, in the Atlantic Coastal Plain.

erosion, and then, after renewed uplift whereby it was extended seaward, to have reached maturity in a second cycle. Still later it lost a large part of its former extension to the northeast by submergence; it now ends at New York harbor — except for drift-covered remnants of a cuesta visible in Long island and other islands farther eastward — so that the ocean reaches and overlaps the gently descending upland or inclined peneplain of the crystalline belt along the New England coast. Various plants, common to the coast of Nova Scotia and the middle Atlantic States, are supposed by Fernald to have reached their northeastern habitat before the coastal plain was lost by sub-

mergence along the New England coast. Southwest of New York harbor, from New Jersey to North Carolina, the coastal plain widens; its border is here interrupted by many elaborately branching embayments that result from the slight submergence of its previously eroded valleys. Some of the long, narrow digitate bays bring tidewater all across the coastal plain to the border of the crystalline belt, as will be seen in the Potomac river (or more properly, estuary) at Washington. In New Jersey the coastal plain is longitudinally belted; a broad cuesta of small relief incloses an inner lowland, which offers a low-grade pathway from New York city southwestward to Philadelphia. In South Carolina and Georgia the coastal plain has a maximum breadth of 120 miles and is not embayed; its seaward margin is there a low, young, featureless plain, beneath which the valleys of even the largest rivers are very slightly incised.

The Older Appalachian Belt. — The greater part of the older Appalachian belt may, as already stated, be best described as an uplifted peneplain, surmounted by subdued monadnocks, irregularly placed, singly or in groups; the peneplain is maturely dissected; occasional areas of weaker rocks are reduced to local peneplains of a later generation. The outer or southeastern border of the belt is determined by the retreating overlap of the coastal plain strata; the inner or northwestern border, by the sudden down-bending of the crystalline rocks under the heavy strata of the folded belt. The breadth of the crystalline belt is greatest in New England, where in spite of the depression by which some of its outer border is submerged, it measures from 130 to 180 miles from southeast to northwest; its inner (northwestern) part reaches altitudes of 1000 or 1600 feet, and is so greatly diversified by surviving monadnocks and incised valleys that the supposed uplifted peneplain is frequently not to be recognized. A great breadth of 170 or 180 miles is again attained

in North Carolina, where the inner part of the belt is as much diversified as in New England. The difference in local aspect of these two broadest parts of the older Appalachians is largely due to the glaciation of the New England area, and is particularly apparent in the valleys: in North Carolina the drainage is typical of normally developed, mature rivers and valleys; in New England small lakes, usually held by drift barriers, are very numerous, and waterfalls abound as the result of local superposition of streams on ledges.

Interruption of the Older Appalachians. — The middle stretch of the older Appalachians, especially between New York and Philadelphia, is narrow, low, and interrupted. It is narrow, because of an inward bend of the overlapping coastal plain border, so that the breadth of the crystalline belt is reduced to 50 miles or less. Even this small breadth was once still smaller, for the overlapping coastal plain strata have been worn off from their original inland extension, stripping a formerly covered part of the crystalline peneplain; the stripped belt is frequently traversed by superimposed streams in narrow gorges, excellent examples of which occur near Philadelphia. The middle stretch is low, seldom exceeding 600 or 800 feet even along its inner border, because its uplift was moderate. Hence the older Appalachian belt does not here constitute a formidable barrier between the coast and the interior, as is the case in New England and North Carolina. Finally, the upland of the middle stretch is interrupted, for it frequently includes infolded or down-faulted areas of weaker rocks, which are now worn down to lowlands beneath the uplifted peneplain of the inclosing crystallines.

Notable among these areas of included weaker rocks are certain limestones and shales in southeastern Pennsylvania, where the resultant lowlands are famous for their fertility; and more important in extent are the red shales and sandstones of north-

westward dip, which occupy a long gently curving strip that extends from north of New York city across northern New Jersey, Pennsylvania, and Maryland into Virginia. This strip is highly significant, in that it obliquely traverses the middle stretch of the older Appalachian belt, where it is narrowest and lowest, so that the crystalline uplands are here partly replaced by lowlands for 300 miles. There are occasional tilted trap sheets contained in the red shale and sandstone series, and these survive in long, narrow, even-crested, monoclinal ridges, of which the Palisades, across the Hudson from New York city, constitute a fine example. Other trap ridges are crossed in a local excursion from New York into Pennsylvania. But the trap ridges are local and discontinuous; the older crystalline belt is so largely interrupted all through its low and narrow middle stretch, that instead of forming a highland barrier, the lowlands by which it is replaced serve as gateways to the interior.

The Four Prongs of the Older Appalachians. — The path of the included red-sandstone strip in the older Appalachian belt deserves particular attention. If one follows the highlands of the crystalline rocks southwestward from their broad expanse in New England to their narrower middle stretch, they are seen to be divided at Peekskill on the Hudson into two prongs by the northeastern point of the weaker sandstone strip; a shorter and low prong on the southeast, which may be called the Manhattan prong because the greater part of New York city, originally called Manhattan, lies upon its extremity; and a longer and higher prong on the northwest, which may be named after the city of Reading, which lies just below its end in east-central Pennsylvania. Similarly, if the broad and mountainous highlands of North Carolina are followed northeastward, they are divided into two prongs by the long southern end of the sandstone strip; a long and low prong in the southeast, extending

past Philadelphia to Trenton; and a shorter and higher prong on the northwest, which terminates near Cumberland in south-central Pennsylvania. These four prongs, the Manhattan and the Reading on the northeast, and the Trenton and the Cumberland on the southwest, serve as convenient points of reference in various local descriptions. Between them, the lowlands of the sandstone strip occupy the whole space between the coastal plain on the exterior side and the lowlands of the folded Appalachians on the interior.

The folded Appalachian belt possesses, especially in Pennsylvania and Virginia, several resistant sandstones, which now

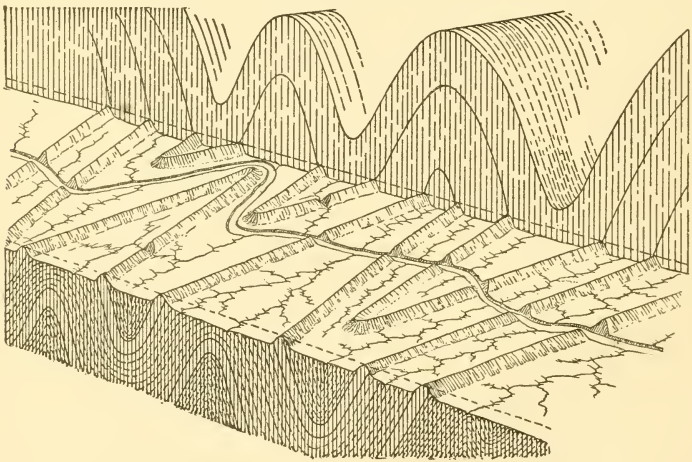

FIG. 2. Diagram of the Allegheny Mountains.

stand up with a relief of from 500 to 2000 feet in long, narrow, even-crested ridges, to which the general name Allegheny mountains is sometimes applied; they follow sharply zigzag patterns in consequence of the gentle pitch given to the anticlinal and synclinal axes at the time of folding. The ridges are here and there cut down in water gaps by transverse streams, which connect

the longitudinal valley lowlands eroded along the belts of weaker strata by revived subsequent streams. Far to the southwest, in Tennessee, northwestern Georgia, and northeastern Alabama, the resistant sandstones of the folded belt are thinner and the ridges are less conspicuous, as we shall see on our return route; they are there frequently notched, so as to form lines of detached hills, known as "comby ridges." In the northeast, the folded belt narrows and is partly replaced by the plateau belt which advances from the west in northeastern Pennsylvania. It is in the synclines of the Pennsylvania section that anthracite coal occurs: the local excursion into Pennsylvania before our departure from New York, gives a view of parts of the district where the eastward advance of the plateau replaces the folded belt. Farther to the northeast, in eastern New York, the ridge-making strata disappear, so that the folded belt is there represented by a lowland known as the Hudson valley, in its breadth of some 30 miles from the high inner border of the older Appalachian highlands to the escarpment of the Appalachian plateau, here known as the Catskill mountains. The plateau ends there. Still farther north, the crystalline mass of the Adirondack mountains replaces the plateau; here the lowlands of the folded Appalachian belt are in large part submerged in the basin of Lake Champlain, which drains northward to the St. Lawrence; and the valley of the St. Lawrence, trending northeastward between the highlands of New England and the Laurentian highlands of Canada, may be regarded as a distant extension of the folded Appalachians. Through the whole extent of the folded belt a moderate regional uplift has caused the streams to incise new valleys, usually mature, beneath the lowlands of the previous cycle, which therefore now deserve to be described as low uplands. This will be apparent as we ascend the Hudson to Albany on the first day of the Excursion.

The Appalachian plateau, now in the maturity of the current cycle of erosion, after having reached a more advanced stage in a previous cycle, is a region of elaborately dissected hills and spurs which branch into a labyrinth of insequent valleys, with maximum local relief of 1000 or more feet. The plateau belt is rather sharply defined along its eastern border by the abrupt change from its nearly horizontal structure to the strongly upfolded structure of the adjoining belt. The eastward advance of the plateau border, where the folded belt narrows in northeastern Pennsylvania, and the end of the plateau belt in the Catskills have already been mentioned. The plateau and the two other Appalachian belts gradually descend southwestward and disappear under the coastal plain of the Gulf States in north-central Alabama. The westward descent of the plateau to the prairies is usually gradual; but it is accomplished in two dissected escarpments in central Kentucky, on account of the occurrence there of two limestones beneath scarp-making sandstones. To the northeast the plateau has a much less extension than the other two belts, because its strata gradually rise on approaching the uplifted mass of the Adirondacks — the group of subdued mountains in northeastern New York — and as the lower members of the plateau series are relatively weak, they are now worn down in a west-east subsequent valley, the Mohawk valley, into which we turn westward from the

FIG. 3. The Coastal Plain of Alabama.

north-south Hudson valley at Albany on our first day out from New York.

Drainage of the Appalachian Belts. — The folded Appalachians are accompanied through their whole length of over 1000 miles by a lowland, which sometimes occupies only their southeastern border, as in Virginia and Pennsylvania; sometimes their entire breadth, as in eastern New York. This long-continued lowland is often called the Great Appalachian valley. Its different parts are commonly known under different names. We follow the part known as the Hudson valley from Fishkill to Albany on our first day's run; we cross the part known as the Valley of East Tennessee after leaving Chattanooga near the end of our return journey.

The Great Appalachian valley is not a simple valley in the sense of being followed by a single river. It is a lowland of erosion that is composed of many broadly opened, head-to-head, confluent, longitudinal valleys, most of which are drained by the subsequent branches of transverse rivers. Some of these rivers deserve special mention.

Four rivers in the middle stretch of the Appalachians, the Hudson, Delaware, Susquehanna, and Potomac, rise in the Appalachian plateau and traverse the two other Appalachian belts and the coastal plain on their southeastward course to the Atlantic. A fifth, the James, rises in the central part of the Great Appalachian valley and traverses the crystalline belt and the coastal plain. To the northeast in New England and to the southwest in North Carolina, the broad and high areas of the older Appalachian belt are not traversed by any river; all Atlantic rivers head in the uplands and highlands of those two mountainous districts. In the north, the inner part of the highlands and the adjacent part of the Great Appalachian valley are drained northwestward, to the St. Lawrence; and in the

southwest, by the Kanawha and Tennessee westward through the Appalachian plateau to the Mississippi — as we shall see at Chattanooga — and by the Coosa southward across the overlapping coastal plain to the Gulf of Mexico.

Settlement and Boundaries. — The embayments of the Atlantic coast line, formed by the submergence of lowlands or valleys,

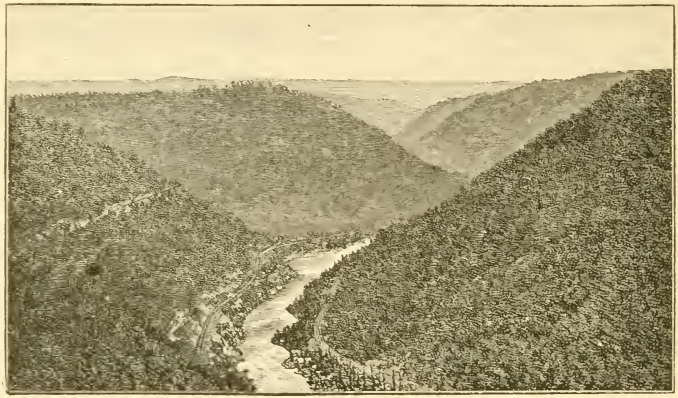

FIG. 4. Canyon of the Kanawha River in the Allegheny Plateau, West Virginia.

determined the location of nearly all the original colonies in the seventeenth century; and with respect to these as centers of influence the boundaries separating them were defined. The generally north-southward trend of the coast line resulted in establishing east-west boundaries in many cases; but the east-west trend of the coast of southern New England determined the north-south boundaries between Rhode Island and Connecticut, and between Connecticut and New York; again, the northeast-southwest trend of the south Atlantic coast produced the northwest-southeast boundaries between North and South Carolina, and between South Carolina and Georgia.

The entrance of some colonies into elongated embayments,

trending southward, cut off the westward extension of the colony next to the east: thus Pennsylvania, first settled at Philadelphia on the estuary of the Delaware, limited New Jersey to a small area; similarly, Virginia limited Maryland, and Maryland limited Delaware. Still more striking is the effect of the north-south trend of the Champlain-Hudson valley, whereby New York gained possession of all the western background of the New England states; hence these states are small, and for the same reason Vermont was in part colonized from the west.

It is no accident that three chief ports of our Atlantic coast, New York, Philadelphia, and Baltimore, are opposite the narrow, low, interrupted middle part of the older Appalachians. It is natural to find that the broader and more mountainous extremities of the Appalachians are of slow development; Maine in the northeast, long ago settled, with an overabundance of harbors on its ragged coast, is still a wilderness in its rugged, forested interior; and North Carolina in the southwest, settled about as early as the other colonies, has since then attracted so few newcomers to its highland country that its present population is in an exceptionally high proportion native born of native born.

All the Atlantic slope was covered with forest, rarely interrupted by treeless spaces, but not infrequently devastated by fires. The early settlers had to clear the land for their farms. The hilly uplands of the interior were the "backwoods," and the daring spirits who penetrated them were the "backwoodsmen" of the eighteenth century, the heroes of many a story of adventure. Their successors in the nineteenth century were the "frontiersmen" on the treeless prairies and the plains, about whom another crop of stories grew up, but of another kind. The heavy labor of clearing the trees from the forested eastern slope finds its memorials in our forms of speech to-day. The stump of

a tree formed a convenient platform for political orators in rural districts; and now a candidate for an office who makes a series of speeches before election day is said to "stump the state." Again, the arduous work of rolling logs demanded the aid of neighbors: "If you'll help me roll my logs to-day, I'll help roll yours to-morrow"; and from this "log-rolling" has come to be the phrase to indicate the exchange of political favors, even in prairie states where no actual log-rolling was ever done.

THE GREAT LAKES AND THE PRAIRIES

An Ancient Coastal Plain. — With the exception of Lake Superior, the Great lakes of the St. Lawrence system — Lakes Michigan, Huron, Erie, and Ontario — are systematically related to an ancient coastal plain which borders the Laurentian highlands of Canada on the south, in that the basins of these five lakes — and of Georgian bay on the east of Lake Huron and of Green bay on the west of Lake Michigan — lie in lowlands on the inside and outside of a fairly well-defined cuesta; the two lowlands and the intermediate cuesta being the necessary result of long-continued erosion on the heavy series of strata, dipping very gently southward and of varying resistance, of which the ancient coastal plain consists.

The Laurentian highlands seem to have served as the old-land and foundation for the coastal plain strata. The highlands consist of very ancient crystalline rocks, enormously deformed, which had been reduced to small relief before submergence caused a change from the erosion of their ancient land surface to the deposition of the overlapping marine strata. Following the later uplift of the compound mass, the stratified formations have, during an undetermined number of cycles of erosion, been broadly stripped from their foundation; finally in the cycle of erosion preceding the glacial period, two important

groups of weak strata near the base of the whole series were reduced to broad lowlands, while an intermediate formation of resistant limestone — known as the Niagara limestone, because it forms the capstone of Niagara falls — survived as a broad cuesta of low relief.

The Niagara Cuesta and the Adjacent Lowlands. — The boundaries of the oldland, the inner (northern) lowland, the Niagara cuesta, and the outer (southern) lowland do not through their whole length trend directly east and west, but — all maintaining a rude parallelism — turn well northward in the middle of the Great lakes region. To the west of this turn, the Laurentian oldland extends southward into the highlands of northern Wisconsin, separated from those of Canada by the unsystematic and unexplained basin of Lake Superior. Similarly, to the east of the turn, an area of crystalline rocks forms the mountainous mass of the Adirondacks in northeastern New York, separated from the Canadian highlands by the depression along which the St. Lawrence river flows northeastward to the Atlantic.

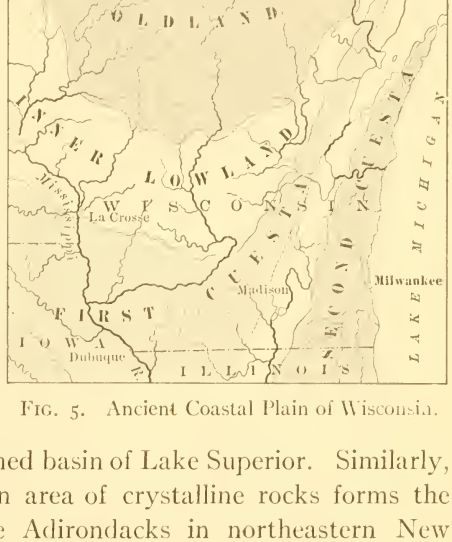

FIG. 5. Ancient Coastal Plain of Wisconsin.

The cuesta-making Niagara limestone thins and weakens westward, and its cuesta effectively disappears in the neighborhood of the Mississippi river. Likewise, it thins and weakens eastward, and its cuesta vanishes in west-central New York.

Thus in the broad lowland of central New York the inner and outer lowlands become confluent, but at the same time the strata of the Appalachian plateau gain strength and thickness eastward, and their dissected margin incloses the lowland on the south; the plateau culminates northeastward in the Catskill mountains, rimmed on the north by the Helderberg escarpment; here a branch of the Erie-Ontario lowland, in the form of the subsequent Mohawk valley, passes between the Helderberg escarpment on the south and the slope of the Adirondacks on the north, as has already been described.

FIG. 6. Ancient Coastal Plain of Ontario and New York.

Relation of the Great Lakes to Glaciation. — It appears probable that in preglacial time — again with the exception of Lake Superior — no lakes existed in this region. If Lake Superior occupies a graben, as has been supposed, its date of origin is unknown. The basins of the other Great lakes seem to be closely associated with glaciation; but the share of crustal warping, glacial erosion, and drift obstruction in producing them has not been determined. Lake Ontario, Georgian bay, and Green bay occupy depressions in the inner lowlands; Lakes Erie, Huron, and Michigan, depressions in the outer lowland; and the Niagara cuesta, often notched into discontinuous relief, separates the two groups; its escarpment faces the lakes in the inner lowland; its back slope descends gently beneath the lakes in the outer lowland.

The Prairie Plains. — Repeated invasions of Laurentian ice sheets southward across the region of the Great lakes into the plains of the upper Mississippi and Ohio drainage river systems, produced extensive sheets of till, often 30, 50, or more feet in thickness, by which the small preglacial relief of most of this region has been very largely concealed. The surface of the till sheets presents the aspect of a plain for scores of miles together, and the greater part of our prairie plains are of this origin. Sometimes the till surface is gently undulating, forming the so-called rolling prairie; occasionally, it is molded in drumlins, as in central New York and in southeastern Wisconsin. Terminal moraines in belts a mile or more in breadth, forming irregular hills and hollows of low relief, with erratic bowlders and lakelets in abundance, mark successive pauses during the final glacial retreat, and thus separate the outer till sheets of earlier development from the inner and later sheets. The moraines are of small relief, but they are often the only hills that are to be seen over long distances on the prairie plains. Some of the outermost till sheets are maturely dissected even by small insequent streams, as in southern Iowa and northern Missouri. All the inner sheets still preserve their initial form, hardly affected by normal postglacial erosion, except in the immediate vicinity of the larger streams.

Lobate Moraines and the Driftless Area. — The advancing ice sheet found a greater unevenness of surface in the region of the Great lakes than farther south; hence the ice became lobate near its margin on the prairies; it advanced farther along the axes of depressions which favored its movement, and suffered retardation where uplands or highlands stood in its way. As a consequence of this, the terminal moraines are arranged in curves convex southward where the ice lobes pushed forward; they unite in northward-pointing cusps where two ice lobes

came together, as was first recognized by Chamberlin. Thus the Great lakes, occupying the deepest parts of the depressions along which the ice lobes advanced, and the moraines which looped around the ends of the lobes, have a strikingly sympathetic arrangement.

A singular result followed from the retardation of the ice sheet on the highlands south of Lake Superior, between the far-advancing ice lobes of Lake Michigan on the east and of Lake

FIG. 7. The Glaciated Area of the Northeastern United States.

Superior on the west. A roughly triangular space, now shared by northwest Wisconsin, northeast Iowa, and southeast Minnesota, remained unglaciated; it is known as the Driftless area, and has been well described by Chamberlin and Salisbury. The ice on the north could not reach it; the ice on the east and west passed by it and closed around it on the south. In an excursion from Madison, Wis., we shall enter the eastern part of the Driftless area, traversing part of the terminal moraine of the Green bay glacial lobe on our way out and back. Within the area of this lobe are many drumlins, the axes of which diverge to the right and left from the mid line of the lobe, thus indicat-

ing that the motion of the ice was deflected towards its free margin. Another important drumlin area occurs in west-central New York, which we shall see on our second day out.

Shore Lines and Outlets of Proglacial Lakes. — It should be remembered that the divide between the St. Lawrence and the Mississippi systems is vaguely determined for much of its length by the "height of land," a broad swell of the till plains, not far south of the Great lakes; and that from the height of land the surface slopes gently northward. During the disappearance of the Laurentian ice sheet, temporary proglacial lakes of increasing size occupied the space between the height of land and the retreating ice front. They had south-flowing outlets, most of which were tributary to the Mississippi system.

The proglacial lakes tended to increase in area as the ice melted back, but the higher lakes abandoned their southward outlets and decreased in size when the retreat of the ice margin allowed their waters to drain into or to become confluent with their lower neighbors. At the same time a slow rise of the land in the northeast — proved by the now inclined position of the shore lines left by the proglacial lakes — caused frequent changes in lake outline and discharge. Many subordinate geographical features of to-day attest these singular events of the past, and are best described in terms of their origin.

The south-flowing outlets of the longer-lasting lakes eroded well-defined channels through the till sheets of the prairie plains, across the height of land and beyond, to different members of the Mississippi system. The little streams that now enter the channels from the prairies on either side are strikingly underfit; not simply because the streams are much narrower than the channels, but because the small meanders of the streams cannot have produced the much larger, smooth-sided curves of the channels. The channels indeed maintain full size above the

head of the present streams up to the height of land, north of which the young or submature shore lines, formed by the lake that fed the large outflowing rivers, may be traced right and left with greater or less distinctness. Silt deposited from the lake waters sometimes cloaks the underlying till of the submerged areas and forms a soil of great fertility.

The shore lines of the proglacial lakes sometimes took the form of offshore sand or gravel reefs (bars), which now appear as low ridges, sometimes the form of low shore cliffs; in drumlin districts, there is an alternation of cliffs and reefs. Although, like the terminal moraines, the shore lines are features of small relief, they are significant in a region where the surface is so generally a smooth or gently undulating plain. We shall see some of the abandoned shore lines south of Lake Erie on the fifth day of our Excursion; and again in North Dakota on our eleventh day.

In some cases the south-flowing outlet of a proglacial lake was abandoned in favor of a lower westward or eastward outlet along the ice margin to a neighboring lower lake; here the channel that was eroded on the disclosed land surface between the lakes ends in a delta plain that was formed in the lower lake basin. Rapids and waterfalls were not infrequently developed along the outlet channels, where resistant strata were discovered beneath the till. As the further retreat of the ice front laid bare lower and lower land between two lakes thus related, the first connecting outlet would be abandoned for a second one farther north; and so on, as long as these conditions were maintained. The level at which the second outlet began to flow must have been a little lower than that down to which the first outlet had then been eroded; thus a series of lower and lower outlets might be formed across a land surface between two lakes. We shall see some channels of this kind

near Syracuse, N.Y., on our second day. Now the outlet channels are all dry, except for the little underfit streams that enter from the side and wander on the floor, and except for small lakes which occasionally occupy the plunge pools below the ancient waterfalls.

One of the longest-lasting southward outlets flowed from a great proglacial lake — known as Lake Agassiz and monographed by Upham — which occupied the broad prairie to-day drained by Red river from Minnesota and North Dakota across Canada to Hudson bay; we shall see its plain and its several shore lines on the eleventh day of our Excursion. The shore lines are found at different altitudes and all rise gradually to the north; their difference of altitude is zero at the outlet, where they all become essentially confluent, and increases northward: thus proving that the rise of land in the north was in progress during late glacial time. There is some reason to think that the rise is still continued, as we shall note on our fifth day, when we pass certain bays, formed by submergence of valleys near the southwest end of Lake Erie.

FIG. 8. The Glacial Lake Agassiz.

The large channel eroded by the outlet, River Warren, of Lake Agassiz is now followed by the underfit, aggrading Minnesota river. The upper Mississippi, a larger river than the Minnesota, follows a wandering course among drift hills, across

till plains and over hard-rock rapids from its many heads in the countless morainic lakes of northern Minnesota through the central part of that state, and enters the channel of River Warren by a young gorge; yet the combined volume of the Mississippi and the Minnesota rivers of to-day, although navigable up to the mouth of the Mississippi gorge, is still underfit in relation to the great channel that it follows. The Twin Cities of St. Paul and Minneapolis stand in intimate relation to these waterways. St. Paul is on the upland north of the channel, just below the mouth of the Mississippi gorge, and therefore close to the head of navigation; while Minneapolis is built around the Falls of St. Anthony at the head of the gorge, and uses the water power there developed in its flour and lumber mills.

The southwestward outlet of proglacial Lake Superior, the channel of which is now occupied by the St. Croix river, joined River Warren not far below the entrance of the Mississippi; in postglacial time, the floor of the main channel has been more aggraded than that of the St. Croix channel, so that the latter river is now ponded, forming Lake St. Croix, next above its junction with the Mississippi. Farther south, a large late-glacial river coming from the northeast, the channel of which is now followed by the Chippewa, caused an active aggradation of the Mississippi channel near the Driftless area, and just above the low barrier thus formed the Mississippi broadens so as to occupy the whole width of its valley, and is there known as Lake Pepin. We shall see several of these subordinate features on our eighth day.

Another important proglacial lake outlet, flowing southwestward from near the southern end of the basin of Lake Michigan, in which the proglacial waters stood at a somewhat higher level than do those of to-day, ran across the prairies to the Mississippi; the Illinois river now follows the channel thus excavated. In

recent years, an artificial canal has been cut through the head of the channel near the present lake; thus some of the water from Lake Michigan is now again tributary to the Mississippi, and carries with it the drainage of Chicago, as we shall see on our sixth day.

Origin of Niagara Falls. — One of the most remarkable of the proglacial lake outlets ran eastward from the great water body known as Lake Warren, which overspread the area of the upper Great lakes, and cut its channel along the depression between the northward slope of the Appalachian plateau margin in central New York and the southward slope of the retreating ice sheet. As the river thus guided performed the offices of the Niagara and the Mohawk, while the St. Lawrence valley was blocked by ice, we may give it the provisional name of the Niagarawk, on the understanding that the name is purely colloquial and that it is not to be used after our Excursion is over. We shall make a local trip southward from Syracuse on our second morning to see some curious gorges cut by the Niagarawk in the spurs of the plateau.

As the ice sheet retreated north of the Niagara cuesta in western New York, Lake Warren overspread part of the Ontario basin. As the ice retreated from the slope of the Appalachian plateau in central New York the Niagarawk flowed at lower and lower levels, and the level of Lake Warren fell with it. Finally the sinking lake was dismembered when the Niagara cuesta was laid bare. The small (northeastern) part, called Lake Iroquois after it became independent of the large part, continued to fall as its outlet, which we may now call the Mohawk, took lower and lower courses. The larger (western) part of Lake Warren was subdivided into the several upper lakes, and of these Lake Erie was sustained by the hard limestones of the cuesta, from which the outflowing river fell

to Lake Iroquois in a great cataract; thus Niagara river and falls were born. The still further retreat of the ice opened the St. Lawrence valley. Then the Mohawk outlet was abandoned, and Lake Iroquois became Lake Ontario. We shall review many of these points on our second and fourth days.

The Treeless Prairies. — The smaller eastern extension of the prairie plains, as in the northwestern half of Ohio, was originally forested; their greater western extent was originally treeless, except in the valleys. To-day these primitive conditions are in part inverted; for the forests of the Ohio prairie plains are for the most part cleared and replaced by farms; while the villages on the treeless prairies always have abundant groves of trees; and near the forested uplands beyond the limit of glaciation on the south, a natural encroachment of woodland is indicated by comparison of earlier and later surveys.

The cause of treelessness on the true prairies has been much discussed. It has been sought in climatic conditions, in the fineness of the prairie soil, and in prairie fires; but it is still disputed. The prairies are not treeless because of insufficient moisture, for their rainfall of about 40 inches annually, with maximum in the summer, is abundant for tree growth; it is only to the west of the 98th meridian that aridity determines the treelessness of the Great plains. Winter cold seems insufficient to prevent tree growth, for forests cover the Laurentian highlands, farther north, where the climate is more severe. Fine soil is believed to retard the spontaneous invasion of trees; and fires are well known to kill out tree growth, while favoring the development of herbaceous vegetation.

Settlement of the Prairies. — It is noteworthy that some of the early settlers of the treeless prairies, coming from a region originally forested, mistook treelessness for a sign of infertility, and selected by preference the forested valley bottoms,

which had to be cleared before they could be farmed; it was only by experiment that they discovered the great fertility of the prairies. Little wonder that, when their fertility came to be appreciated, they were rapidly invaded by the more enterprising members of the agricultural population on the hilly Atlantic slope, as well as by throngs of immigrants.

The possible wealth of the great domain in the Ohio basin was long ago recognized and foretold. In his "Analysis of a General Map of the Middle British Colonies" Lewis Evans wrote in 1755: "Were there nothing at stake between the crowns of Britain and France but the lands on that part of Ohio included in this map, we may reckon it as great a prize as has ever yet been contended for between two nations. But if we further observe that this is scarce a quarter of the valuable land that is contained in one continued extent, and the influence that a state vested with all the wealth and power that will naturally arise from the culture of so great an extent of good land in a happy climate, it will make so great an addition to that nation which wins it, where there is no third state to hold the balance of power, that the loser must inevitably sink under his rival. . . . How different this from the conceits of those who would represent some single colonies as equal to all England, . . . as that they might one day be able to dispute dominion with England. . . . Supposing the colonies were grown rich and powerful, what inducement have they to throw off their independency? National ties of blood and friendship; mutual dependencies for support and assistance in their civil and military interests with England; each colony having a particular form of government of its own and the jealousy of either's having superiority over the rest, are unsurmountable obstacles to their ever uniting to the prejudice of England upon any ambitious views of their own. But, that repeated and continued ill-usage, infringements of their dear-

bought privileges, sacrificing them to the ambition and intrigues of domestic and foreign enemies, may not provoke them to do their utmost for their own preservation, I would not pretend to say, weak as they are: but while they are treated as members of one body and allowed their natural rights, it will be the height of madness for them to propose an independency, were they ever so strong. If they had any ambitious views, a strong colony of a natural enemy to England on their borders would be the only article that would render any attempt of independency truly dangerous; and for that reason it becomes those who would regard the future interests of Britain and its colonies to suppress the growth of the French power and not the English in America."

The continuity and uniformity of this vast prairie region, seldom broken by landmarks, hastened its settlement during the first half of the nineteenth century, and favored its subdivision by the Land Office of the National Government by a rectangular and not overaccurate system of meridians and parallels, a mile apart, which were marked by posts at their corners and halves, for convenience of sale. Each square mile is called a section; and a square of 36 sections forms a township. As a result of this method of subdivision, nearly all the common roads to-day follow the north-south or east-west section lines; it is chiefly the railways that follow oblique lines.

The flatness of the till sheets often gave trouble to the early farmers by detaining the run-off after spring thaws and heavy rains: the faint depressions remained too wet for plowing until too late in the season for the growth of a good harvest. This difficulty has now been greatly reduced by extensive systems of ditches, constructed under the direction of drainage commissions; a striking economic response to physiographic environment. The universal covering of till made it difficult to secure stone for road building, and not only the country roads

but the streets in the villages as well were next to impassable in wet weather. The introduction of vitrified brick as a pavement for village streets has worked a marked improvement in the last twenty years; but the country roads, made by "road machines" which scrape the soil up from either side and heap it in the middle, are often hopelessly bad. But again the flatness of the prairies has turned to their advantage in facilitating the economical construction of single-track steam railways during the second half of the nineteenth century, and in favoring the development of electric railways during recent years.

THE GREAT PLAINS

Boundaries of the Great Plains. — A broad belt of horizontal structure, low relief, dry climate, and treeless surface extends northward from Texas across the United States and far beyond in Canada. The belt gained the general name of the Great plains from early explorers who crossed it on their way to the Far West; and it has never received any better appellation. It is sharply limited on the west by the Rocky mountains through most of its length, with the supplement of some Basin ranges in New Mexico. It is vaguely limited on the east, where a gradual transition is made near the 96th or 98th meridian to the outrunner of the Laurentian highlands in the glaciated peneplain of northern Minnesota, to the drift-covered prairies of Iowa and northern Missouri, and to the homologue of the Appalachian plateau in the Ozark plateau of southern Missouri. More significant than change of surface is the eastward increase of rainfall from an annual total of less than 18 or 20 inches, with a minimum of less than 12 in the arid southern part of the Great plains, to a more abundant precipitation east of the 98th meridian.

The province of the Great plains is traversed by the shallow valleys of many east-flowing rivers. It is interrupted by the

denuded, domelike uplift of the Black hills in South Dakota, and invaded by the subdued Ouachita mountains in Oklahoma. It is undercut by the denuded district of central Texas, so that here, where it is known as the Llano estacado, its eastern border is formed by a descending escarpment, elaborately dissected. But through all of its vast extent, the broad expanse of a treeless surface of low relief is the dominating characteristic, well warranting the name of the Great plains.

We traverse this extensive province twice: once across its northern part on our way west through North Dakota and Montana, and again across its middle on our return east through Colorado and Kansas; we thus gain views of two districts of unlike physiographic development.

The Northern Plains. — The northern parts of the Great plains in the United States exhibit all the features of a peneplain, more or less perfectly developed in the cycle of its erosion, and now slightly dissected by the wide-spaced valleys of its revived rivers. It has an elevation of about 5000 feet near the mountains and of 2000 feet near the Missouri river at Bismarck. A large fraction of this part of the Great plains has been invaded by an ice sheet from the northeast, even to the base of the Rocky mountains in northern Montana; but the ice seems to have been almost inert, as it did no great work either in erosion or deposition over most of the area; chiefly to the east of the Missouri river in the Dakotas are till sheets and terminal moraines of topographic importance.

Far east of the Rocky mountains, where the strata of the plains are weak, the surface passed the stage of peneplanation in the former cycle of erosion and was reduced over large areas to a geographical plain. The few little residual hills that remain, sparsely scattered, only serve to emphasize the rule of planation by their exception to it. Nearer the mountains, where some

of the strata are more resistant and where volcanic rocks are not infrequent, the erosion of the former cycle was less complete, and residual reliefs, chiefly in the form of scarped mesas, ragged cuestas, and dike ridges, interrupt the intervening peneplain. The local relief of some of these residuals near the mountains measures several thousand feet, and thus attests the enormous erosion that the region thereabouts suffered during its peneplanation. The Crazy mountains, maintained by a network of dikes, are the strongest of these residual forms; they will be

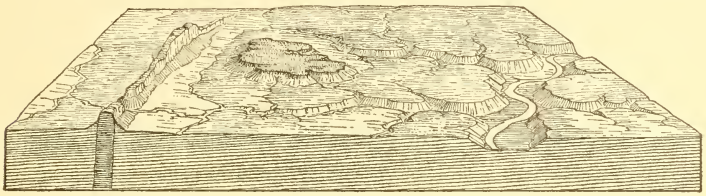

FIG. 9. Diagram of Dike and Mesa on the Great Plains.

seen north of Livingston, Montana, in the morning of the day on which we turn south to enter the Yellowstone national park.

The rivers of the Great plains have incised mature valleys of moderate depth, as if in consequence of regional uplift. The valley sides are dissected by numerous insequent ravines, known as "coulees"; the uneven surface thus produced near each river is known as the "breaks"; but a few miles back, the peneplain remains undissected; hence the district must be on the whole regarded as young in the present cycle, though its rivers and their valleys are already mature.

The Badlands. — Where the strata are composed of fine-grained sands and clays little indurated, the "breaks" are more extensively developed into "badlands" — the "mauvaises terres pour traverser" of the early French "voyageurs." The notable peculiarity of such districts is the fine texture of their dissection

by elaborately branching insequent valleys and ravines, so that a contour line may have a thousand indentations in a mile. The cause of so elaborate a dissection is found in the dryness of the climate, which makes vegetation scanty, and still more in the easy removal of the semi-indurated clays and sands by the run-off of the occasional rains, so that active though intermittent erosion replaces the slow and steady process of soil-creeping over the entire surface, and every little rill of rain water carves its own channel. The enormous extent of the intricately eroded surface, in which the horizontal strata of the badlands are thus exposed, has contributed effectively to the discovery of the vertebrate fossils which abound in certain districts; and these fossils, taken with certain details of structure — especially gravel-filled channels — suffice to show that the strata of the badlands are in large part of fluviatile origin, and not lacustrine, as was formerly supposed.

The Central Plains. — The central part of the Great plains which occupies eastern Colorado and western Kansas, sometimes known as the High plains, has a different aspect from the northern part, above described. Like the northern part, the central part was enormously denuded in an earlier cycle of erosion, and thus reduced to the small relief of old age, but then instead of suffering dissection by revived rivers, it suffered burial under the deposits of aggrading rivers. Thus the present surface is widely covered by heavy fluviatile deposits of gravel, sand, and clay, which are coarser and thicker near the mountains, but which become finer and thinner eastward; and the residual reliefs of the buried peneplain are completely concealed over great distances. But the rivers have now returned to the work of erosion, and have incised mature valleys beneath the surface which they had previously built up; wet weather side streams have dissected the valley sides; the fluviatile plain remains

uncut only at a distance back from the new valleys. Where thus preserved in its original form, it is often extraordinarily smooth; a windmill standing by an isolated ranch is seen in the distance on the level but convex plain before the ranch comes into sight, thus repeating the experience of first seeing the masts and then the hull of a vessel on the level but convex plain of the sea.

Occupation of the Plains. — The dryness of the plains assigns them chiefly to pastoral occupations; their population is scanty and scattered. Cattle raising is their main industry; but it may be remembered that the rich grasses of the prairie states support vast numbers of cattle on compact farms of comparatively small area, in contrast to the broad domain of a cattle ranch over which the herds must range, if they are to subsist on the scanty herbage of the plains. Ranch life demands horsemanship; many an eastern boy, whose childhood has been passed on foot in a manufacturing village, but who goes west in early manhood to seek a living, becomes, after a short " tenderfoot " apprenticeship, as proficient in the arts of tracking and lassoing, and as expert and enduring a horseman as a nomad of the steppes. To-day small automobiles are commonly used to cover the long distances that separate outlying ranches from the village of their railroad station.

The rivers that issue from the Rocky mountains are now eagerly used to irrigate the adjoining plains, and many prosperous agricultural colonies have thus been established not far east of the mountain base. Dams and irrigating canals were at first the work of individual settlers, later of communities and districts; now the most extensive projects are carried out by the Reclamation service of the National Government; in the last ten years, seventy-seven million dollars, received from the sale of public lands, have thus been expended in the western third of

the United States, and immense sums of money have already been received from the sale of dry or desert lands thus irrigated. Between the piedmont belt that is reached by abundant irrigating streams and the area of increasing rainfall, several hundred miles farther east, the plains are driest and most thinly populated. Dry farming, an innovation of recent years, is attempted where no irrigation is possible. It has not yet been tried through a long enough period to make sure that it is more than a precarious occupation, sometimes profitable, occasionally disastrous; it is invited more by the low price of arid lands than by the certainty of crops; it can be best practiced by those who have enough hope or capital to survive one or two years of failure in two or three of success.

The railroads that cross the Great plains are deservedly the subject of marveling comment. A map shows an amazing number of lines, each of which seems to go so far with so little local support! But close as the competing lines appear to be on a map, they are separated by large distances on the ground; and besides an active local traffic they have an enormous long-haul business between the center or east of the country and the far western states.

THE WESTERN UNITED STATES

The Cordilleran Region. — From the Great plains to the Pacific coast, there is a complicated succession of mountains and plateaus extending south into Mexico and north into Canada, for which the general name, Cordilleras of North America, has been proposed. The easternmost member of this great complex is the Rocky mountain system, which extends from northern New Mexico across the United States and far into Canada, and is limited on the east by the Great plains and on the west by three other members, the Plateau, the Basin range, and the

Lava plateaus provinces. The western members of the Cordilleran complex are the Sierra Nevada of California, the Cascade range of Oregon and Washington, and the coast range of California, Oregon, and Washington, bordering the Pacific. Throughout the central part of this extensive region, even the intermont basins and plains have an altitude of from 3000 to 6000 feet; the mountain summits frequently exceed 10,000 or 12,000 feet; the greatest altitudes are reached by Mt. Whitney (14,898 feet) in the southern Sierra Nevada in California and by Mts. Massive (14,424 feet) and Elbert (14,421 feet) in the Sawatch range of the Rocky mountains in Colorado. The contrast between the structural complications of the western United States and the structural simplicity of the eastern two thirds of the country is strikingly illustrated in a long section, which we shall see in the National Museum in Washington.

THE ROCKY MOUNTAIN SYSTEM

Area and Subdivisions. — The name, Rocky mountains, is advisedly limited to the ranges which rise near the eastern border of the system, including, for example, the Front range of Colorado, the Big Horn range in Wyoming, and the Lewis and Clark range in Montana. The ranges farther west have no collective name subordinate to that of their system as a whole; chief among them are the Wasatch range which borders the basin of Great Salt lake on the east, the Uinta range which adjoins the Plateau province on the north and is singular in trending east-west, and the Bitterroot range which divides Montana and Idaho. The variety of form in an extensive mountain system defies generalization; hence the following statements must be understood as open to many exceptions.

Structure and Origin. — The ranges of the Rocky mountain system consist of an ancient and rather even foundation of

deformed crystalline rocks, unconformably covered by a heavy series of stratified formations, which vary greatly in composition and resistance. The compound mass suffered extensive but not extreme deformation and great denudation; it was then again thrown into new disorder by warping and faulting, whereby the present system of large reliefs was developed and the present cycle of erosion was introduced. The evidence of the first deformation is manifest enough in the abundant outcrops of disturbed strata; the evidence of the second and lesser deformation, after the action of great erosion on the previously deformed mass, is not so manifest, but is found partly in the occurrence of uplifted peneplains, as in Colorado, and partly in the lack of systematic relation between rock resistance and mountain altitude, as in Montana. The weaker structures are now already worn down where they were raised in the secondary uplifts, and thus exhibit the reduced altitudes which usually characterize their feeble resistance; the resistant structures are more significant of a two-cycle origin of their forms, in occurring at small as well as at great altitudes. The crystalline rocks as well as the resistant sandstones and limestones, truncated by extensive erosion, sink into basins about as often as they rise into mountain crests; and for this singular behavior no explanation is so reasonable as the one above stated — first noted for this region in 1883 — namely, a second deformation following the long-continued erosion that was introduced by an earlier deformation.

Special Features of Certain Ranges. — It is characteristic of the Rocky mountain system that the secondary warping and faulting was frequently not sympathetic with the more pronounced deformation of earlier date. The disorder introduced by the earlier deformation was seldom, as noted above, extreme; it was commonly of large scale, in the form of broad-arching or monoclinal flexing, with more or less faulting or extensive over-

thrusting; seldom in the form of close folding. A grand development of monoclinal flexing, with some faulting and rare folding, characterizes the eastern border of the Front range in Colorado; the delimitation between the plains and the mountains was effected by this simple structure, but it is essential to note that the difference of level introduced by the great flexure was essentially obliterated in the first cycle of erosion, and that the present difference of altitude between the plains and the mountains is largely due to the more rapid erosion of the weaker strata of the plains after a second uplift without renewed flexing. This will be well seen in our excursion from Denver. Broad arching is best exemplified in the Uinta range in northeastern Utah; this is the range which is exceptional in its east-west trend; it is historically interesting as the locality from which Powell, over forty years ago, drew his inference as to the antecedent origin of Green river which traverses the range from north to south; while Emmons, at about the same time, explained the same relation by superposition near the close of a period of erosion and deposition by which the earlier broad arching was separated from a later uplift which gave the present altitude to the range.

The Wasatch range, facing Great Salt lake on the east near the city of similar name, is a huge syncline with east-west axis, enormously reduced in a first cycle of erosion and now diversified by subsequent valleys after its renewed massive uplift. The great meridional fault, by which these mountains are truncated along their west base, is one of the best examples of a later deformation which gave the present altitude of the range, but was discordant with the earlier one which produced its synclinal structure. We shall have good opportunity of seeing the features dependent on these two deformations in local excursions during our visit to Salt Lake city.

Overthrusts of extraordinary extent occur in the northern

part of the system, where — in striking contrast to the simple monoclinal flexure of the Front range in Colorado — the heavy stratified series of the Lewis and Clark range, which there fronts the Great plains, was driven a number of miles eastward over much younger strata. The irregular escarpment in which the resistant overthrust strata now terminate is believed to be the result of revived erosion in the present cycle of mountain development — corresponding to the cycle in which the plains were peneplained — following extensive erosion in the previous cycle, which was introduced by the great overthrust.

The Yellowstone national park is exceptional in being largely built up of heavy lava sheets which constitute the most eastern and elevated part of the great lava-covered area which occupies so large a surface in Washington, Oregon, and Idaho; the Absaroka range, next east, is built of massive volcanic agglomerates. The latter is abundantly dissected; the former, slightly so; hence the scenery of the park is rather that of a plateau than that of a mountain range.

The scenery of the Rocky mountains is disappointing to travelers who expect to find in them a repetition of the Alps. In spite of possessing many summits that rise more than 14,000 feet above sea level, their effective relief is diminished by the great altitude of the plains or basins from which they are seen. The forms of the ranges within the United States are frequently massive; many summits are dulled or rounded by long-lasting erosion; the climate of the region is too dry to supply extensive snow fields or to form large glaciers; but the observer who looks to see what these mountains are, instead of what they are not, will find much to hold his attention.

The Intermont Basins. — The Rocky mountain system is a true mountain chain, in that it contains many basins encircled by ranges. The basins are areas of relative depression produced

by down-warping or down-faulting in the later period of deformation; for even the most resistant rock structures dip into them and pass beneath the heavy cover of lacustrine or fluviatile deposits with which the basins are aggraded. The inclosing ranges are trenched by the deep gorges of outflowing rivers, which in many cases have an antecedent habit. In some examples, the depth of the trench is not sufficient to allow the dissection of the basin deposits; in other examples the trench is deeper than the former surface of the basin deposits, so that they are now maturely dissected. The San Luis "valley" in southern Colorado and northern New Mexico, the southernmost of all the basins, is drained southward by the Rio Grande through a deep gorge in the encircling mountains, and represents the first type; its broad floor is undissected; much water that sinks into the unconsolidated strata of the basin filling is now regained by artesian wells. The Green river basin of southwestern Wyoming and northeastern Utah represents the second type; the plain surface of its former filling is now thoroughly dissected by the branches of Green river, which escapes by a deep canyon through the Uinta mountains on the south; this canyon was the first one which Powell and his party descended in boats on his memorable exploration of the "Colorado river of the West."

The lofty intermont basins in Colorado are known as "parks." In the afternoon of the day on which we reach Denver, we shall cross South park, rimmed on the west by the Mosquito range and on the east and north by the highlands of the Front range; its level floor lies at an altitude of nearly 10,000 feet, as yet undissected by its river, the South Platte, which flows northeastward through a rapidly descending gorge. Directly west of South park lies the deeper and narrower basin of the upper Arkansas, between the Sawatch range on the west and the

Mosquito range on the east. We shall have a fine view of this aggraded basin on the day of our approach to Denver; the day after leaving Denver, we shall see the Royal gorge by which the Arkansas passes through the Front range from the southern end of the basin.

Drainage of the Rocky Mountain System. — The irregular grouping of mountain ranges and depressed basins results in producing a complicated interlocking between the headwaters of the several river systems by which the region is drained. The long Missouri-Mississippi system and its branches, the Platte and Arkansas, receive the outflow of many basins that discharge eastward to the plains; the Rio Grande carries southward the waters of the San Luis "valley"; the Colorado receives from its chief branches, the Green and the Grand, which rise in the southwestern ranges and basins, the large volume that enables it to traverse the deserts of the far Southwest; several small rivers flow westward into the basin of Great Salt lake; and the tributaries of the Columbia carry off the drainage of the northwestern part of the system in Montana and Idaho. We shall see something of all these rivers in one part or another of our journey. We shall first cross the continental divide on our way westward between the Missouri and Columbia systems, after leaving the Yellowstone national park; we shall cross it again on our way eastward between the headwaters of the Grand-Colorado and the Arkansas-Mississippi; we shall ascend to the divide in a local excursion from Denver; and we shall cross it, going and returning, in the Plateau province.

Two features of interest regarding the divide between the Columbia and Missouri-Mississippi systems deserve special mention. A branch of the former in northern Montana has its head at the eastern base of the mountains, and passes through their whole breadth on its way to the Pacific; it receives indeed

the drainage of a small area of the plains, and is destined to receive more, for its westward descent is much more rapid than the eastward descent of its Missouri-Mississippi competitor. It is noteworthy that this exceptional case lies in the region of the great overthrust, and it may be in consequence of it. The Great Northern railway utilizes the deep-cut pass thus made; it ascends the long slope of gently inclined plains, and begins its westward descent at the eastern base of the mountains.

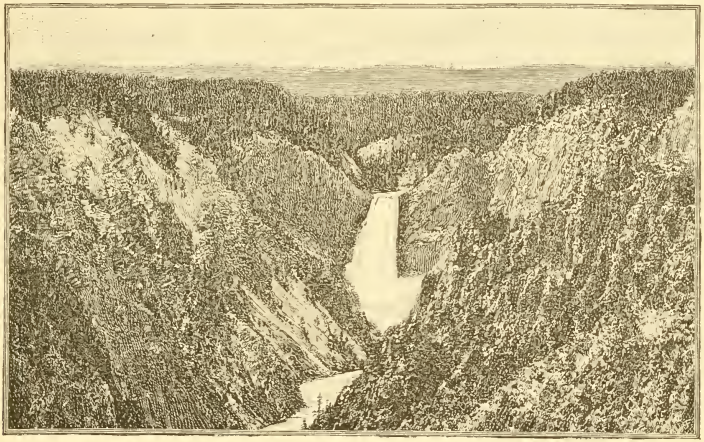

FIG. 10. Falls of the Yellowstone River.

The sources of the Snake river, the largest tributary of the Columbia, rise in the lava plateaus of the Yellowstone national park. They formerly received the outflow of Yellowstone lake; but, as first announced by Goode, the Yellowstone river gnawed by retrogressive headwater erosion through the rim of the lake basin on the northeast and thus captured the lake waters, which thereupon abandoned their former westward outflow and rapidly intrenched their new course, which we shall see in the Yellowstone canyon on the last days of our visit to the park. This

is an excellent example of a recent capture, for the diverted lake outlet has not yet had time to grade its new course; the lofty falls of the Yellowstone plunge into the head of their narrow canyon. A little west of the lake, a lateral stream has built an alluvial fan across the narrow valley floor of the former lake outlet; the fan now forms a part of the continental divide, and its stream, sometimes following a radius which leads it to Atlantic drainage, sometimes to Pacific drainage, is therefore known as "Two-ocean creek."

Features due to Glaciation. — Existing glaciers in the Rocky mountain system within the United States are of small dimensions. The largest are in the Lewis and Clark range of northern Montana; here a district has recently been set apart as Glacier national park; it unfortunately lies outside of our route.

The large and abundant glaciers of the Glacial period have left manifest traces of their work in valley-head cirques and sharpened peaks, in overdeepened troughs and hanging lateral valleys, and in terminal moraines, as well as in cirque-basin and trough-bottom lakes. In the ranges of Colorado, the enlargement of valley-head cirques sometimes succeeded, but frequently failed, in sharpening the summits that had been given rounded forms by normal preglacial erosion; the glaciers there were long enough to descend into the intermont basins, as in the upper valley of the Arkansas, where we shall see their terminal moraines; but they were not long enough to descend to the plains at the eastern mountain base. In northern Montana, the valley-head cirques are much larger; their enlargement has frequently obliterated all traces of preglacial summit form; their troughs reach to the eastern mountain base and their terminal moraines advance on the plains, where, singularly enough, these piedmont glaciers encountered the margin of the vast Laurentian ice sheet which overran the plains from far northeast.

An interesting question of terminology is associated with the normal and glacial mountain forms of this region. Many of the Rocky mountains have been so well subdued that their domelike summits and rounded spurs might be given the name of "Mittelgebirgsformen," even though they reach altitudes of 11,000 or 12,000 feet, which would place them among "Hochgebirge." It is only to summits of somewhat greater altitude, which like their fellows were very generally subdued and rounded in preglacial time, but which now in consequence of glacial sapping and sharpening have gained Alpine boldness, that the name, "Hochgebirgsformen," may be applied. It should be remembered that excellent "Hochgebirgsformen" are found in the mountains of Spitzbergen at the moderate altitudes of "Mittelgebirge," because of the intense glaciation that has there taken place, and we here see that many summits in the Rocky mountains have "Mittelgebirgsformen," although their height would warrant their being classed with "Hochgebirgen"; hence it would seem to be advisable to give up these empirical terms, which find inductive justification only within the small area of central Europe, and to introduce either empirical terms that better represent the facts of broader observation, or explanatory terms that adequately represent the development of mountain forms.

Settlement. — The mountain ranges of the Rocky mountain region have been more thoroughly explored by the prospector with his pick than by the geologist with his hammer. Ore deposits are abundant. Numerous mining camps have sprung up; many of them have been short-lived and are now in ruins; others of greater endurance have rich gold or silver ores, as at Leadville and Cripple Creek in Colorado, or copper ores, as in the subdued ranges near Butte in Montana. Agricultural settlements in the intermont basins promise to be more per-

manent; they are frequently well supplied with streams, which furnish electric power during their descent in the mountain flanks, and feed irrigation canals on the basin floor. The forests of the mountain sides are of increasing value, and are now largely under inspection of our Forest service; but they have been fearfully devastated by fires, many of which have been due to rank carelessness. Overlarge flocks of sheep have yielded great profit to their owners, but they have often caused devastation by uprooting the scanty herbage on mountain slopes.

The habit of using meridians and parallels for the early definition of boundaries in unsurveyed regions finds abundant application in the western United States. On the prairies and the plains, such boundaries are not inconvenient; and in so far as they were used to define territorial limits in advance of explorations and surveys, they served an excellent purpose even in the mountains. But with the increase of population boundaries of this kind introduce many practical difficulties. The division of the public lands in the mountain region into square-mile sections has repeatedly resulted in awkward property lines; as when a valley head is included in a section of which the greater area lies on the other side of the dividing ridges; and cases are known in which state or international boundaries cut off a high-walled cirque from the trough into which it opens, and associate it with other troughs from which it is separated by almost unscalable cliffs.

There are now six railroad lines which cross the Rocky mountains, and other lines are in the building or prospect. Their construction has involved serious engineering problems, but nothing so difficult or so expensive as the great tunnels through the Alps. The first line, the Union Pacific railway, finished nearly half a century ago, traversed the Front range in southern Wyoming, where the local relief of the arched peneplain in the

mountain crest is so small that many a traveler crosses it without knowing that he is in the Rocky mountains. On other lines, it has been a not uncommon practice to cross a pass by a temporary line, which is afterwards abandoned for a tunnel at a lower level.

THE PLATEAU PROVINCE

Location and Structure. — Southwest of the Rocky mountain system and east of the Basin range province, there is an elevated region occupied by a heavy series of horizontal strata, in which the leading features are extensive plateaus of moderate local relief, standing at different altitudes and separated by long escarpments; this is the Plateau province. Its altitude varies between 5000 or 6000 and 11,000 or 12,000 feet; it is here and there bedecked by volcanoes and lava flows in various stages of dissection, and it is occasionally trenched by profound canyons. Its climate is dry and its surface is for the most part treeless; forests occur only at altitudes above 7000 or 8000 feet. Its population is scanty and scattered.

The Plateau province is structurally subdivided by faults and monoclinal flexures, generally trending about north-south, by which adjacent masses or ' blocks " have been raised to different altitudes. The region is no longer in its first cycle of erosion, but in the early stages of a second cycle that was introduced, after the attainment of an advanced stage of erosion in the first cycle, by strong regional uplift — probably about synchronous with the later deformation of the Rocky mountain system — with moderate or negligible movement on the earlier lines of displacement. Hence the present plateaus frequently exhibit broadly stripped surfaces of erosion, which coincide rather closely with a resistant formation. We shall see a fine example of a stripped highland surface in the Kaibab plateau and its

southern extension, the Coconino, during our stop at the Grand canyon of the Colorado, which cuts off the lower and smaller part of this single structural element from the higher northern part. The Kaibab block is structurally separated by an east-dipping flexure from a lower stripped plateau, the "Marble platform," on the east, and by a strong fault from another stripped plateau, the Kanab plateau, on the west; but it must be remembered, as will be further explained below, that since these dislocations were produced, great denudation has taken place, followed by renewed uplift; it was the latter uplift which introduced the present cycle of erosion, a cycle that is so little advanced that nearly all of its valleys are young or submature canyons.

Escarpments. — The escarpments of the Plateau province are of two classes. Those of the first class are the result of advanced normal erosion, chiefly in the first cycle, on horizontal or gently inclined strata of varying resistance, with refreshment by renewal of erosion after the later uplift. As the plateau-making strata, although of great thickness, have but five or six important alternations between strong capping formations and weak sapping formations, the erosional escarpments within the limits of each plateau block are few in number and of strong relief; they are usually irregular, sometimes ragged in outline. Where the forms of the first cycle are still preserved, as occasionally happens far from the present canyons, the escarpments have the dulled form of late maturity; but where renewed erosion has caused active sapping, the escarpments are steep and bold; extensive landslides occasionally accompany the refreshment of form thus introduced.

In the mature erosion of a typical plateau of essentially horizontal structure, a platform gently ascends from the top of one escarpment to the base of the next higher one. This is the case

to the north of the three stripped plateaus above mentioned, where a series of south-facing escarpments of strong relief rises like a flight of gigantic steps to the highest plateaus of the province in southern Utah; the escarpments are for the most part steepened by the revived erosion of the present cycle, but by far the greater part of the erosion by which their strata were stripped from the lower plateaus on the south was accomplished during the earlier cycle, when the whole region stood lower than now.

In other parts of the province where the structure is gently inclined, the platform which crowns an escarpment descends through a long back slope; and the steep face and the long back slope taken together give the relief of a typical cuesta. The finest examples of this kind occur in a northeastern subdivision of the province, which we shall cross on the way from Utah to Colorado, a subdivision which was called by Dutton the San Rafael swell, because of its gently domed structure. It has been enormously denuded, and its harder members now form ragged cuestas disposed in irregularly concentric ovals. In this district occur the laccoliths of the Henry mountains, made famous by Gilbert's early studies. Our route here lies north of the center of uplift and follows — mostly at night — a broad subsequent depression between the back slope of one cuesta on the south and the lofty and elaborately dissected scarp of another on the north; the latter is known as the Book cliffs and is one of the strongest features of its kind in the whole province. The eastern part of the swell is traversed by the Green river, which, after joining with the Grand, forms the Colorado; all these rivers follow inconsequent courses, which led Powell to regard them as antecedent; some other explanation may perhaps be found in connection with the long period of erosion which followed the doming of the structure, and with the broad uplift which introduced the present cycle.

The escarpments of the second class are associated with faults, and like the escarpments of the first class are subdivisible into two kinds. The simpler kind includes escarpments which have been produced directly by faulting, although the fault face may now be more or less maturely dissected. These may be called fault scarps; their height during the earlier stages of their cycle is a good measure of the faulting. Scarps of this kind must have been common in the early stages of the first cycle through which the Plateau province has passed; but they are relatively rare to-day, being now limited to localities where new or renewed faulting was associated with the introduction of the second cycle. Chief among the latter is the maturely dissected fault scarp by which the Plateau province is separated from the less elevated Basin range province on the southwest; we pass this great escarpment twice, on our way from the Colorado canyon to Phœnix in southern Arizona, and on the return; but at night on both trips; we shall see it from the Roosevelt dam.

The second kind of escarpments associated with faults is more abundant to-day; it includes those examples which are developed by the erosion of a second cycle acting unequally on different parts of a broadly uplifted peneplain — or subdued surface of late maturity — that had been worn down on a faulted structure in a preceding cycle. Wherever weak strata stand next to resistant strata along a fault line in such a worn-down surface, the more rapid removal of the weaker strata necessarily results in the development of a scarp, which must be maintained for a time close to the fault line by the resistant strata; hence the scarps of the second kind may be called fault-line scarps, in distinction to the fault scarps of the first kind. The altitude of fault-line scarps is not a measure of the faulting, as it is in fault scarps, but of the thickness of the weak strata removed by renewed erosion. The slope of a fault-line scarp is not

necessarily directed toward the down-thrown block, but towards the weaker strata, which may occupy either the uplifted or the down-thrown block. If the weak strata are in the down-thrown block, the renewed fault-line scarp may be called resequent; if on the opposite side, obsequent. Resequent fault-line scarps are abundant in the Plateau province; obsequent examples are of rarer occurrence. The abrupt descent of the Kaibab plateau to the lower Kanab plateau on the west is a dissected

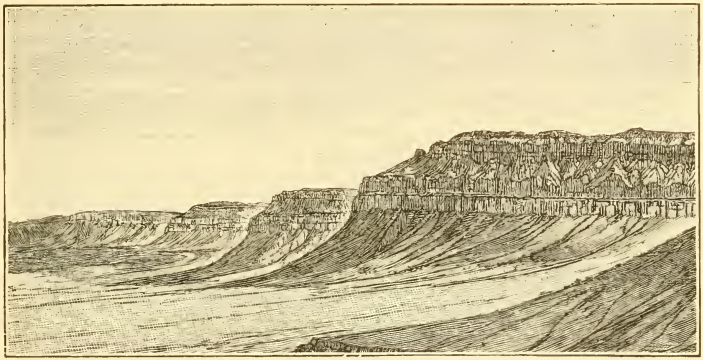

FIG. 11. Hurricane Ledge, a dissected Fault-line Scarp.

resequent fault-line scarp; the western border of the Uinkaret plateau, west of the Kanab, is another fault-line scarp, known as Hurricane ledge.

Monoclinal Flexures. — Peculiar features occur where the plateau blocks are separated by monoclinal flexures instead of by faults. If the erosion of the two cycles is such that the land surface of to-day is determined by a single resistant formation, stripped of the originally overlying weak strata on both sides of a flexure, the flexure will be revealed in the existing form, more or less ripped by consequent ravines and gorges; the eastern border of the Kaibab plateau, where its heavy limestones descend

to the Marble platform on the east, is of this kind. But if the flexed structures were worn down to low relief in the first cycle of erosion, in such a manner that a resistant stratum plunges down at the flexure, separating weaker strata on either side, then when uplift and renewed erosion are introduced, the plunging monoclinal formation may assume a greater or less relief in a rectilinear ridge between two lowland belts. An extraordinarily fine example of this kind is found near the Arizona-New Mexico line on the Nutria monoclinal flexure, admirably described by Dutton; we shall probably make a brief stop on it.

Volcanic Features. — The volcanic features of the Plateau province are abundant and varied. Young cinder cones and lava

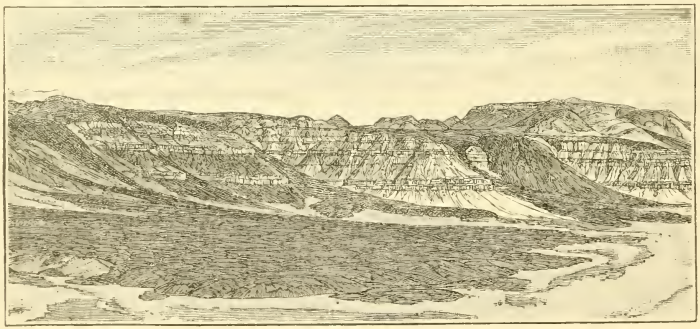

FIG. 12. Lava Flows on the Plateaus of Arizona.

flows occur on the plateaus north and south of the Colorado canyon; some of the flows are so recent that they cascaded into the canyon after it had been eroded to about its present depth at a point fifty miles or more west of the place where we visit it, and obstructed the river for a time. They have now been cut through, but their remnants are still clearly seen clinging to the canyon wall. Great volcanoes, now elaborately dissected

or reduced to unevenly subdued forms, are scattered over the stripped plateaus. Mt. Taylor is one of these; it surmounts a lava-covered plateau in northwestern New Mexico, north of our route; the surrounding surface, free from protective lava, is worn down to a lower level. Many volcanic necks occur in this worn-down district, as if the present surface were below the surface at the time of volcanic action. Mt. San Francisco in north-central Arizona forms a noble landmark over the arid plateau to the north of our route on the morning of our approach

FIG. 13. Volcanic Buttes near Mt. Taylor.

to the Colorado canyon; its Alpine flora includes several species of plants identical with those found in northern Greenland. Some of the most lofty members of the Plateau province, for example, the Awapa plateau in southern Utah, in which the highest members of the great sedimentary series of the Plateau province are found, appears to have been preserved from the widespread erosion which removed the rest by a heavy capping of lava. This plateau stands at an altitude of nearly 12,000 feet; it is covered by a fine coniferous forest; from its southern cliffs one may descend across successive normal retreating escarpments to the broadly stripped plateau of northern Arizona — unfortu-

nately named the "Colorado plateau" — in which the Colorado canyon is intrenched.

Canyons. — The canyons for which the Plateau province is justly famous are the work of revived rivers in the present cycle of erosion. They seldom follow fault lines; the Grand canyon of the Colorado traverses northwestern Arizona in an irregular southwestward course, with little regard for several strong flexures and faults of meridional trend. The work of the present cycle is so little advanced that many tributary streams have not yet cut down their upper courses significantly below the surface of the uplifted plateaus, and vast areas — lowlands of the former cycle, plateaus of the current cycle — are therefore still undissected with respect to present baselevel. This we shall see as we follow the Little Colorado river soon after entering Arizona. Yet even the smaller tributaries of the large, deeply intrenched rivers have cut down side canyons so effectively toward their mouth that they have already established accordant junctions with the master river; none but the smallest tributaries fall from normally hanging side valleys, in which an accordant junction with the main canyon bottom is not yet established.

Only in exceptional cases are the canyons of the present cycle narrow slits with vertical walls; the best example of this kind is the canyon of Virgin river, a branch of the Colorado in southwestern Utah, where the entire depth of the canyon is cut in massive and resistant sandstones. Most of the canyons are submaturely opened, because the intrenchment of their rivers has disclosed an alternation of resistant and weak formations; the latter have worn back into slopes, and force the cliffs of the former to retreat. It is particularly in the magnificent disclosure of crustal structure afforded in escarpments and canyon walls that the immediate relation of structure and form is here made

apparent, even to the geologically uninitiated observer; so that the whole population of this region is predisposed towards an understanding of the leading principles of earth sculpture, and the geologists who first explored it involuntarily became physical geographers.

Yet even in the widest canyon, the contrast between the work of excavation now accomplished and the widespread denudation which remains to be accomplished in the removal of the bordering plateaus enforces the youthfulness of the present cycle upon the observer's attention. If one hesitates to believe that so vast a task as the removal of broad plateaus can ever be accomplished, the recognition of the origin of the broad plateau surface, itself the product of an essentially completed cycle of erosion before the excavation of the canyon was begun, is an excellent antidote to such skepticism. And for those who look deeper, there are buried plains of erosion, long preserved and now revealed as geographical fossils in the bottom of the Grand canyon, which are silent but eloquent witnesses to the verity of completed cycles of erosion in the earth's history.

Settlement. — The Plateau province seems destined to remain a thinly inhabited region, in which the annual visitors to its scenic wonders almost outnumber its fixed population. As the home of ancient cliff dwellers and as the site of many pueblos on the natural strongholds of mesas, it possesses a great archeological and ethnological interest; as a region of dry climate, it attracts and cures many consumptives, known as "lungers" in local slang. Its fuller occupation demands irrigation, and irrigation is difficult or impossible in a plateau country, where most of the few rivers flow in deeply intrenched canyons. The newcomer repeatedly says: "If water could only be led over this dry country!" — before he is reconciled to take things as they are and make the best of them. Rivers, which so generally

prepare pathways for travel and traffic, here form inverted barriers; the Grand canyon of the Colorado has been well characterized as "a mountain range of nothing, upside down." It cuts off the northern part of Arizona disadvantageously from the rest.

THE BASIN RANGE PROVINCE

Boundaries of the Province. — Systematically considered, this province is an arid region of disordered structure, with abundant volcanic rocks in the northern and western parts. According to Gilbert, it was reduced to subdued or low relief in the cycle of erosion introduced by the deformation of its structure, then broken into great blocks, commonly measuring from 10 to 30 miles east and west, and from 50 to 100 miles north and south, and diversely displaced and tilted; the uplifted blocks now being so elaborately dissected that they show few traces of their uplifted form, and the depressed blocks being buried out of sight by the waste from the uplifted blocks.

The northern part of the province is abruptly limited on the west by the dissected fault scarp of the Sierra Nevada; on the east by the dissected fault scarp of the Wasatch range — the westernmost member of the Rocky mountain system in this latitude — and of the Plateau province next south; on the north there seems to be a gradual transition to the little disturbed ava plateaus of Idaho and Oregon; to the south, the province widens, passing around the end of the Sierra Nevada to the Pacific coast, and around the Plateau province and the southern end of the Rocky mountains to the Great plains in central New Mexico, and then slowly narrowing again and reaching far across the international boundary into the Republic of Mexico. In the north, some of the faulted and tilted blocks are little dissected, as if that region had been lately invaded by block-making def-

ormation; to the south, in Arizona, some of the ranges are so greatly worn down that their residual cores are bordered with smooth rock floors, thinly veneered with alluvium.

The most striking topographic feature of this great province is the isolation of its separate ranges. Many of them have a marked individuality, standing well apart from their fellows, the intermont spaces being occupied by the broad alluvial floors of the aggraded depressions. In this respect the Basin range province is in strong contrast to the Rocky mountain system, in which the basins with their aggraded floors are isolated from one another by the continuous complex of mountain ranges.

Fault-block Mountains. — The detailed features of a tilted fault-block mountain range in the young or submature stage

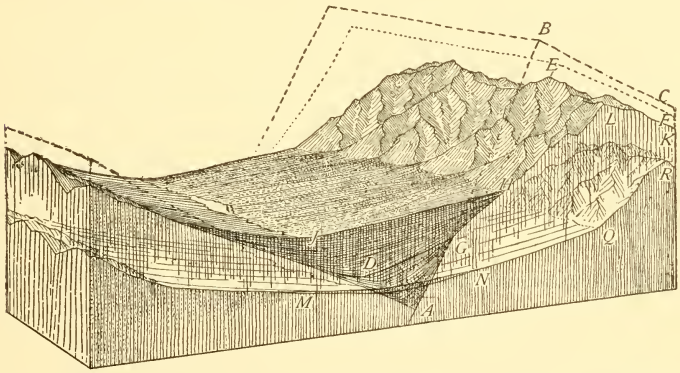

FIG. 14. Diagram of a dissected Block Mountain and a Waste-filled Trough.

of its new cycle are: 1. the want of connection between the general trend of the range and the strike of its rock structure; 2. the gradual fall of the back slope, in which the prefaulting surface, now more or less dissected, descends from the crest of the tilted block to an irregular base, where it disappears under the alluvium, so that the hardest rocks may occur at any altitude;

3. the truncation of all structures along the simple but not necessarily rectilinear base of the fault face, remnants of which are still to be seen, little changed, in the triangular facets of spur ends between narrow ravine mouths; while the upper part of the fault face is destroyed by the widening of the ravines, and the crest is pushed back and notched by the recession of the ravine heads; 4. the outspreading bowlder-strewn fans of waste that are built far forward from each ravine mouth into the broad intermont depressions; while one is ascending the long, gentle slope of such a fan, his eye comes to misjudge its inclination, taking it for more nearly level than it really is; and if an irrigating ditch is then met, the water in it seems to be running up hill; 5. the frequent indication of renewed faulting that is found in rectilinear scarps traversing the gravel fans near and parallel to the mountain base.

In the later stages of its cycle of erosion, a fault-block mountain must lose many of these features; the mountain base must retreat from the fault line, the ravines must widen, the spur ends must lose their triangular facets and become rounded; the back slope must lose all traces of the pre-faulting form, and the stronger structures must be left in relief as subsequent valleys are excavated along the weaker structures; but still the resistant structures that remain in strongest relief in the range crest may descend slowly to the base of the back slope, where they disappear under alluvium. In a far-advanced stage of the cycle, the residual hills of a fault-block range would terminate vaguely in sprawling spurs, having no necessary relation to the initial relief or to the fault line. As already intimated, there is some reason for thinking that the Basin range province includes examples of fault blocks in all stages of erosion.

Climate of the Basin Range Province. — The aridity of this region deserves further emphasis. The mountains sometimes

support tree growth, but the intervening plains have only a desert vegetation, in which sagebrush and many kinds of cactus abound. There is but one large river, the Colorado, which flows from its sources in the Rocky mountains across the province to its mouth at the present head of the Gulf of California; the "present head" being here specified, because the former head of the gulf, cut off by the delta of the Colorado, is now evaporated to a dry and flat basin floor, slightly below sea level; formerly a desert, but destined to reclamation by irrigation. All the other streams of the region disappear within it; hence it contains many basins of interior drainage, and from this feature as well as its numerous mountains, its name is derived.

The altitude of the intermont alluvial plains in the northern part of the province, which we cross between San Francisco and Salt Lake city, varies from 4000 to 5000 feet; and from this district there is a general loss of height south and southwestward. It is therefore not by reason of inclosure by mountain barriers but because of insufficient rainfall that all the drainage of the Basin range province does not join the Colorado river and reach the sea. Most of the streams wither away on the gravelly slopes of the intermont depressions soon after leaving the ravines and valleys in the discontinuous ranges; these little streams often show a diurnal fluctuation, shrinking into their ravines during the noon hours of unclouded sunshine and active evaporation, and advancing beyond the mountain base only during the cooler hours of the nights; occasionally a small trunk stream is formed along the axis of a depression, dwindling as it flows, and at last vanishing, even on a forward slope, in the hot and dry summer weather; or flowing farther after rains in the winter or spring and then ending in a shallow water sheet on a smooth clay floor, or playa.

Shore Lines of Extinct Lakes. — The well-preserved shore lines of recently extinct lakes — named Lakes Bonneville and Labontan, after early explorers of the region — are features of detail in the northeast and northwest part of the Basin range province, made well known through the monographs of Gilbert and Russell. The lakes were of extremely irregular outline,

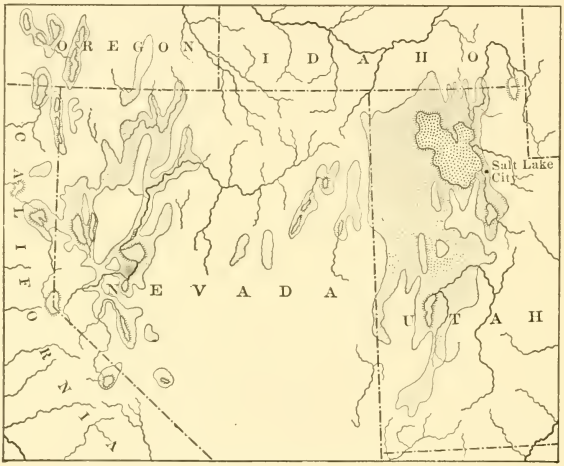

FIG. 15. Lakes Lahontan and Bonneville.

as they rose upon the discontinuous mountain ranges; Bonneville measured about 300 miles north-south, and Labontan over 200. The shore-line features include cliffs, beaches, beach ridges, V-bars, and deltas; these features now stand at various altitudes up to nearly 900 feet above the basin floors, thus indicating great fluctuations of lake level. The highest beaches of Bonneville mark the level of an outlet to the north, by which its waters temporarily overflowed to the Snake-Columbia system. We shall see many of these curious features as we cross Nevada and while we are at Salt Lake.

Population. — The population of this province is concentrated about mines in the ranges and upon irrigated farms of restricted area on the intermont plains. Great spaces are uninhabited and must remain so. There is no water to irrigate them. The mining towns wax rapidly during a period of increasing production, and then wane as the yield of the mines falls off. Virginia city in western Nevada is now a waning town of this kind, but, in 1880, it had a population of about 11,000; $350,000,000 worth of gold and silver has been taken from its mines on the famous Comstock lode. Goldfield, in one of the north-central ranges, is of more modern date, still growing. Rich copper mines are worked in the mountains of southern Arizona.

The irrigated districts, commonly known as "settlements," but fully deserving to be called "oases," are more steadily prosperous; Salt Lake city, Ogden, and Provo, all of which are on our route, are the best examples. Many of the smaller settlements have reached the limit of agricultural population; others, in which large reclamation works have been lately established, have a promising future, as we shall see at Phœnix, Arizona.

The daring enterprise of American railroad construction is nowhere better illustrated than in the Basin range province. It was surprising enough on the Great plains; it is amazing on the intermont deserts, where the lines traverse seemingly endless vacancy in order to connect distant centers of population. The line which we take from San Francisco to Salt Lake city, originally known as Central Pacific railroad, but now operated by the Southern Pacific company, was a bold project when it was constructed forty-five years ago; this line, with the Union Pacific line from Omaha to Salt Lake, made the first "Pacific railroad," and awakened a world-wide attention. Now six other

main lines cross the Cordilleran region, and the construction of the last one, which closely parallels the first through the deserts of the Basin range province, was unnoticed except by those immediately interested in it.

THE LAVA PLATEAUS

General Features. — North of the Basin range province, between the Rocky mountain system on the east and the Cascade range on the west, lies a region about as large as France, covered with lava. A vast period of time must have elapsed during the accumulation of the heavy series of lava flows, for the deep canyon of Snake river between Idaho and Oregon discloses the petrified remains of forests which grew at many successive horizons in soils formed on the lava and ash beds. The inequalities of the preëxistent surface are sometimes revealed in the same canyon, where the river has cut through the lavas to their uneven foundation, and there the canyon narrows. The border of some of the younger flows in the eastern part of the region contours around advancing mountain spurs and forms embayments in valleys; and isolated mountains occasionally rise above the lava surface. But although certain parts of the lava plains have a recent appearance, other parts must be of relatively ancient origin; for some districts have been dislocated by strong monoclinal flexures and faults. Some of the lava masses that are thus displaced form young block mountains, as in southern Oregon, a district made classic by Russell's vivid descriptions; the mountain blocks are little dissected, and the depressions between them contain numerous lakes; the Klamath lakes, which we shall pass the day before reaching San Francisco, belong here. Other displacements are, however, much older, for the relief that they initiated has been almost destroyed by normal erosion, as we shall see at Coulee city, the day before

reaching Seattle. Part of the lava-covered region has been broadly uplifted and elaborately dissected, as in the so-called Blue mountains of southeastern Washington and northeastern Oregon. Moreover, other lava fields, which may be regarded as extensions of those in this province, have been uplifted in the Rocky mountains, where they form the highlands of the Yellowstone national park; and a western portion of the lava fields has been uplifted in the Cascade range, where there has been abundant dissection after uplift.

The Lava plateaus are drained by the Columbia, which enters from the ranges of Canada on the northeast, and by its chief tributary, the Snake, which comes from the Rocky mountains on the east. Both rivers have strongly intrenched courses; part of the canyon of the Snake, with benched walls of lava flows and ash beds, is only less remarkable than that of the Colorado.

During the glacial period, the great bend of the Columbia river around the northern side of the lava plateau was obstructed by ice streams, which crept down into its valley from the mountains of the northwest; the river then rose in a large lake upstream from the barrier thus formed, and the lake found an outlet across the lava plains to the southwest. The lake outlet persisted long enough to erode a canyon in the lava beds, at the head of which its waters plunged down in a group of superb cataracts. We shall see their site near Coulee city.

THE PACIFIC MOUNTAIN SYSTEMS

The Cascade Range. — West of the Lava plateaus rises the Cascade range: a mass of deformed crystalline rocks partly covered with lavas, volcanic agglomerates, and tuffs, broadly uplifted with warping and faulting and now maturely dissected. The range rises to altitudes of 6000 or 8000 feet, and is crowned with several huge volcanoes, of which Mt. Rainier is the chief.

Some observers have thought to recognize, in the prevailing approach to equality of summit altitudes, the traces of a peneplain, formed before the upheaval of the range and dissected afterwards; but in the absence of undissected uplands of small local relief at mountain-top altitude this explanation does not seem to be completely established.

The volcanoes that crown the range are all more or less deeply dissected; the largest are, beginning on the north near the Canadian boundary: Mt. Baker, 10,719 feet, Mt. Rainier, 12,526, and Mt. Adams, 12,470, these three being north of the transverse valley of the Columbia, which separates Washington from Oregon; and Mt. Hood, a dissected cone rising a short distance south of the Columbia. In southern Oregon, near the termination of the range, a large volcano, once of great height, has lost its upper part by engulfment; and in the huge caldera thus formed lies Crater lake, where we shall camp two nights and a day. Lassens peak, a volcanic cone in northern California, rises on the boundary between the Cascade range and the Sierra Nevada. Many caverns are found in the recent lava flows that descend the eastern slope of the mountains in southern Oregon.

All the higher valley heads of the Cascade range have been the seat of local glaciers, which have left their marks in cirques and troughs. Of the latter, the most significant is the one occupied by Lake Chelan in the eastern slope of the range in northern central Washington; the walls of the trough are of simple form, the lateral valleys hang above the lake waters, the trough bottom is below sea level. These features were first recognized and explained by Gannett, in an article that opened the modern understanding of the importance of glaciers as eroding agencies.

The Columbia river has cut a deep valley through the Cascade range, as if it had had and held an ancient right of way, in ante-

cedent fashion; but east of the range the lava plains are covered by widespread, continental deposits, believed to be in large part lacustrine and containing an important mammalian fauna; and in so far as these deposits record the temporary obstruction of the river and its transformation into a lake upstream from the rising mountain barrier, it should not be regarded as a perfect example of the antecedent class. Its gorge has been obstructed locally by landslides, now marked by rapids. We see a narrow part of the gorge, known as the Dalles, where the river flows between bold walls of lava, the morning before our visit to the city of Portland. Another river, the Klamath, much smaller than the Columbia, traverses the Cascade range near its southern end, in northernmost California, and discharges the waters of the Klamath lakes from the depressions among the displaced fault blocks of southern Oregon.

The Cascade mountains offer an exceptionally fine example of a range that has a wet slope towards the neighboring ocean and a dry slope towards the interior. The wet slope bears a dense coniferous forest; the dry slope is nearly or quite treeless. During our traverse of the range on the day of our arrival at Seattle, we shall see the farthest eastern extension of the forest on the ridges north and south of the treeless Yakima valley; then as we ascend to the valley head, the forest invades lower and lower levels, and after crossing the pass, the whole slope is heavily tree-covered. The dry eastern valleys, where they are open enough for occupation, are famous for their fruit farms; most noted are the Wenatchee and Yakima valleys, in the latter of which we shall spend a morning. The western slope of the range supplies a vast amount of lumber; after felling the trees, the labor of clearing away the stumps is a severe preliminary to agriculture. The abundant waterfalls of well-fed streams are increasingly utilized as sources of electric power. Salmon

ascend the streams from the sea every summer in vast numbers; a great amount of canned salmon is shipped to eastern markets.

The Sierra Nevada. — Conceive a mountain mass, composed partly of massive granites, partly of compressed and metamorphosed sediments, worn down to moderate or small relief and then overspread with lava streams in its middle and northern part; next raised and tilted as a huge fault block, with its scarp to the east and its longer slope to the west, and in this position submaturely dissected as a whole, and strongly glaciated in its higher parts: such seems to be the general quality of the Sierra Nevada of California. Uncounted qualifications must be added before this oversimplified scheme can parallel the complicated facts of nature; yet it serves a useful purpose in affording a framework on which appropriate details may afterwards be embroidered.

The general trend of the range is from northwest to southeast; its length is about 500 miles. It begins near the northern border of California, but fails to reach the southern border by about a fifth of the length of the state, of which the southeastern part is occupied by members of the Basin ranges. The highest summit of the Sierras is Mt. Whitney, nearly 15,000 feet, in the southern part of the range near its eastern scarp, where an abrupt descent is made to the desert floor of Owens valley. In the district of Mt. Whitney the mountainous highland must have had a significant relief, presumably of subdued expression, before faulting and uplifting; it is now a rocky wilderness above the tree line, in which, if one may judge from descriptions by W. D. Johnson, Lawson, and Gilbert, glacial erosion seems to have reached a late mature stage; that is, the summit forms have been so far encroached upon by the enlargement of valley-head cirques, that the sharpened peaks of to-day are only the much-reduced remnants of the presumable preglacial domelike forms.

The upper parts of the preglacial valleys have been converted into overdeepened troughs, of which the Yosemite valley is the most extreme example; so extreme indeed that only pronounced glacialists like Gannett and D. W. Johnson regard it as of glacial origin. On the eastern side of the range, opposite the Yosemite, glaciers of steep descent excavated troughs in the mountain slope and deposited large terminal moraines on the desert lowland near Mono lake, a district that has been well described by Russell.

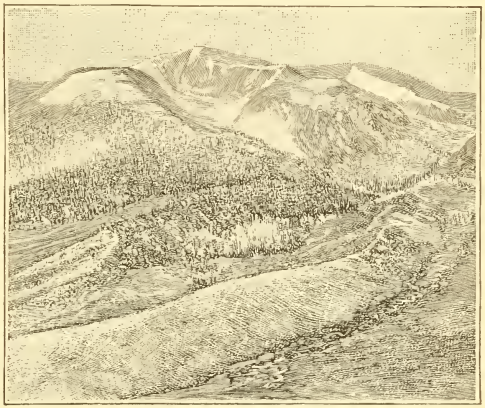

Fig. 16. Glacial Moraines in the Sierra Nevada, California.

In the region of the Yosemite valley and farther north, the former cycle of erosion was more advanced, and the worn-down mass is only submaturely dissected in the present cycle; that is, it presents rolling highlands, here and there dominated by isolated residual masses or monadnocks, and interrupted by sharply incised, narrow-floored valleys. As a whole the highlands gradually descend to the west, and at the base of the range pass under the broadly aggraded floor of the great valley of California. The most elevated eastern parts have been glaciated and bear abundant lakelets in small rock basins; here and on the interstream uplands of the western slope, the stream-heads have hardly begun the erosion of the present cycle; but they soon descend into sharply cut canyons, of which the greatest depth is roughly midway between their heads in the eastern

highlands and their mouths at the western base of the range. The tributary streams do not cascade into the main valley after the fashion of tributaries which enter troughs of glacial excavation, but join the larger streams in normally accordant fashion by lateral valleys of rapid descent which cut the main valley walls down to the main stream.

The eastern slope of the range in its middle and northern part seems to have been produced by compound faulting of subrecent date; basins, more or less aggraded and in at least one case holding a fine lake, Tahoe, occupy the depressions in the highland thus produced. The eastern base of the range all along its length is marked by long fans and slopes of coarse waste or "wash," which stretch far into the adjoining depression. Near the northern end of the range, Pitt river cuts across it from the arid basins in the northeastern angle of California, but no special study has yet been made of its canyon.

Volcanic features are abundant in the central and northern part of the Sierra Nevada. The gigantic cone of Mt. Shasta, 14,350 feet in height, rises at the western base of the range close to its northern end, and near the northern boundary of California. We shall pass around its western base the day before reaching San Francisco. Abundant lava streams cloak the western slope of the range; but the region has been uplifted and deep cañons have been eroded since the lavas were poured out, so that the flows, which presumably followed wide-open valleys of a worn-down region, have now assumed the form of table mountains.

While rainfall is abundant all the year round on the Cascade range of northern Washington, it is reduced to moderate amount and limited to the winter months in southern California, where the climate is essentially subtropical, like that of the Mediterra-

nean. Still farther south comes the rainless belt of the trade winds, so that the desert of the interior reaches the ocean shore in the Mexican peninsula of Lower California. The forests which clothe all the western slope of the Sierras in the north, retreat to its higher parts in the south. The heavy snows of the high Sierra justify its second title; but anything less worthy to be called "Nevada" than the state of that name, made up

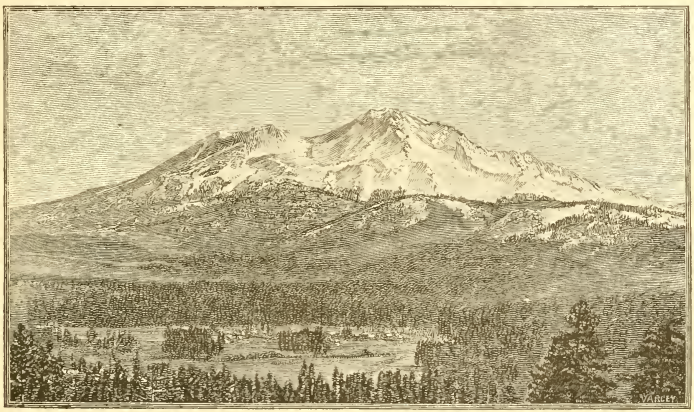

FIG. 17. Mount Shasta.

of desert plains and barren mountains in the Basin range province east of the Sierras, can hardly be imagined.

The Coast Ranges. — The Olympic mountains in northwestern Washington, with altitudes of 6000 or 7000 feet, occupy the peninsula between Puget sound and the Pacific; they appear to be a domelike uplift dissected by radial valleys, with exceptionally heavy rainfall and dense forests. Thence southward, a complex of mountains of moderate altitude, maturely dissected or subdued and known as the Coast range, extends to the pronounced "knee" in the shore line of southern California. They are forested in the north, thinly treed or bare in

the south. Like so many other ranges in various parts of the world, and like all the mountains thus far mentioned in this book — except a few lava-block ridges in southern Oregon — the Coast range is no longer in the first cycle of erosion introduced by the deformation of its rocks. Its northern part appears, according to Diller, to be now in the maturity of its second cycle, following the uplift which closed a much more advanced stage of its first. In some localities the worn-down surface of the first cycle seems to descend beneath the modern deposits of the valley of California, thus indicating that the movement which raised the present range was a warping uplift of part of an extensive peneplain, another part of which was depressed in the trough of the great valley. Farther south, the studies of Lawson indicate repeated dislocations and dissections in the Coast range belt. The continuation of these movements into recent times is shown plainly enough by the occurrence of newly raised beaches and lately drowned valleys along the Pacific border; and more especially by the displacement of block on block along a great fault line, recognized as such twenty years ago, but made notorious by the slight snap which produced the San Francisco earthquake of 1906.

The Coast ranges are traversed by several rivers, among which the Chehalis, Columbia, Umpqua, Rogue, and Klamath deserve mention. The Columbia is navigable in its lower course, but is obstructed by shoals at its mouth. More important for ocean commerce is the channel maintained through the range to the north-central coast of California by the formerly combined waters of the Sacramento and San Joaquin rivers, now drowned by recent submergence so as to form the Golden gate and San Francisco bay, the most important reëntrant south of Puget sound on this little embayed coast. We shall have a good view of it as well as of the general course of the earthquake fault

line during an excursion to Mt. Tamalpais, on our second day in San Francisco.

Puget Sound, Willamette Valley, and the Valley of California. — A depression, more or less pronounced, separates the Coast ranges from the Cascades and the Sierras. We shall follow it from Seattle to Sacramento. Its northern part in northwestern Washington is occupied by a branching arm of the sea, known as Puget sound, which has at first sight the appearance of being a drowned system of normal valleys, but which has been explained very differently by Willis, who regards it as occupying the troughs maintained by great glaciers which built up the extensive drift deposits that inclose it. The disposition of the arms of the sound and of several neighboring troughs partly occupied by lakes, suggests that the ice at the head (southern part) of the sound, advanced southward with somewhat divergent motion. Terminal moraines and widespread outwashed gravels — these being exceptional in lacking a forest cover — are found on the height of land before the transverse valley of the Chehalis river is reached. The irregular outline of Puget sound produces numerous eddies in the strong tidal currents that swing in and out; and as a result many points of land, or cuspate forelands, have been built out from the slightly cliffed shore line. The tides are peculiar in exhibiting a well-defined diurnal inequality, in contrast to those of the Atlantic coast, where successive tides are of nearly the same range.

The Willamette valley of northwestern Oregon contains stratified deposits in the lowlands among its hills, which suggest its former occupation by a branching water body, possibly an arm of the sea. Successive heights of land separate the hilly lowlands of the Willamette, Umpqua, Rogue, and Klamath valleys.

The "valley" or plain of California is a remarkably well-

defined physiographic unit, occupying two thirds of the length of its state. Its longer axis measures about 450 miles; its width, about 50 miles. Needless to say, it is in no respects a "valley" of erosion, but a heavily aggraded plain, occupying a trough of deformation which appears to have been produced by the depression of part of the extensive worn-down region, the adjoining uplifted parts of which are now seen in the Sierra Nevada and the Coast range. The valley plain receives many good-sized rivers from the sharply incised valleys of the Sierras on the east, fewer and smaller ones from the valleys of the Coast range on the west. It is drained from the north by the Sacramento, of which the apparently antecedent Pitt river forms the headwaters; and from the southeast by the San Joaquin; it thus resembles two plains of the Po, placed together mouth to mouth. The broad and gently sloping alluvial fans which extend forward from all the valleys of the Sierra are admirably adapted to agriculture, aided by irrigation. Two of the fans in the southern part of the alluvial plain raise the surface a little above the southernmost part, which therefore holds a marshy water sheet, known as Tule lake.

Settlement of the Pacific Slope. — The Pacific coast was little known to the rest of the world in the first half of the nineteenth century. The greater part of its length had been settled from Mexico, hence the present abundance of Spanish names; it exported hides from Californian ports and furs from farther north. Then the discovery of gold-bearing quartz veins and gravels in the western slope of the Sierra Nevada made it the goal of an adventurous army of invading immigrants from all parts of the world. Some made the journey thither by the long, two-ocean voyage around Cape Horn; some crossed the Isthmus of Panama between shorter voyages on the Atlantic and Pacific; some dared to make the journey across the continent overland.

There are now few survivors of those modern Argonauts, the original "Forty-niners," of California, but their children are worth meeting, for the tales of danger and hardship that they can repeat, as told them by their parents. The feverish years of roving life in mining camps have been followed by a more settled life, and at present agriculture predominates as the occupation of the growing population. The great alluvial valley plain, first occupied in its natural condition for cattle raising, then cultivated in wheat fields, now gives its greatest yield from irrigated fruit farms.

Nearly twenty years passed after the discovery of gold before the first Pacific railroad was completed across the continent, and more than thirty before the Northern Pacific railroad reached the forested shores of Puget sound. Hence the active settlement of the Far Northwest did not begin until about thirty years after the rapid invasion of California, or some thirty years ago. Instead of having a population that was largely supplied by the initiative of adventurous individuals, among whom men were in great majority, the Northwest has been largely settled by families, carried quickly by the organized enterprise of railroads to terminal cities that were mapped before they were built.

A third type of settlement is found in the southern part of California. There the climate is delectable in its mildness; but rainfall is deficient, and the larger growth of population has been delayed until the modern development of irrigation has made agriculture and fruit raising highly profitable. As a characteristic result, a duty has been enacted by Congress on lemons, whereby the crop of southern California can compete to advantage in our eastern markets with that of southern Italy, where labor is cheap, life is not ambitious, and the expectation of profit is small.

In recent years engineering enterprise has been actively applied to the use of the streams that descend from the mountains.

Huge reservoirs have been built in the southern ranges for storage of water, to be used in the drier season for irrigation on the piedmont alluvial plains; where water is not overabundant, it is led in cemented ditches to guard against loss by seepage, and even in pipes to protect it from evaporation. Streams of rapid descent are used to produce electric power, which is transmitted astonishing distances to cities on the coast.

THE MISSISSIPPI RIVER

The Embayment of the Gulf Coastal Plain. — On our return journey we visit an embayment of the Coastal plain of the Gulf States, which demands brief description, with especial regard to the great river that follows its axis. The embayment is evidently the result of a down-warping of a preëxistent land surface, whereby the sea was permitted to advance 500 miles north of its present shore line in the Gulf of Mexico. Its waters then and their deposits now overspread the depressed area, and thus to-day the plateau of southern Missouri and the mountains of central Arkansas are separated from Appalachian features of similar structure and form in Tennessee and Alabama by a broad reentrant of the southern coastal plain.

Since the first uplift of this region, the strata of the coastal plain have been sufficiently worn away to permit the development of a fairly well-defined cuesta, which sweeps northwestward across Alabama and Mississippi, and southwestward across Arkansas; but its relief is small, and now, since the latest uplift of the region, whereby the youngest coastal borderlands have been added to the continent, the cuesta has been maturely dissected by streams of almost insequent habit, so faint is the dip of the cuesta-making strata. The inner lowland, excavated on weak, underlying strata, has in Alabama and Mississippi a rich black soil, and is famous for its cotton plantations; it is there

that the Negro population frequently exceeds that of the Whites.

The Mississippi River. — It seems probable that the lower Mississippi did not exist as the trunk of its upper branches before the down-warping of the uplands whereby the embayment of the coastal plain was foreshadowed; and at that early time, the basin of the upper Mississippi very likely drained westward into the sea that occupied the site of our Great plains. The uplift of great tracts of the continent then conspired to turn the drainage of a vast land area southward; and thus the lower Mississippi gained its great size. The lower river once formed, the last uplift of the region caused the immediate intrenchment of its valley to a slight depth below the uplands of the dissected coastal plain on the east and west, the rapid broadening of its flood plain to a width of from 30 to 50 miles, and the extension of its delta in the singular finger-like projections, known as "passes."

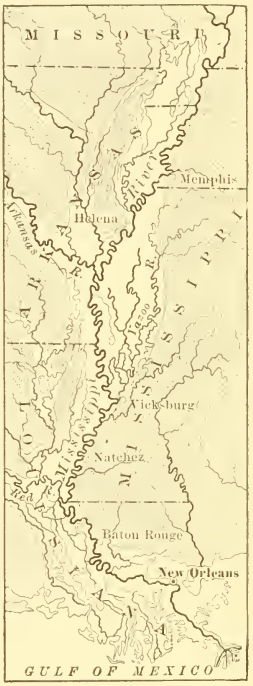

FIG. 18. The Mississippi Flood Plain.

From the head of the embayment, marked by the city of Cairo, at the southern extremity of Illinois, to the mouth of the Mississippi, the direct distance is 560 miles; the length of the meandering river is 1060 miles. The altitude of the river at Cairo at ordinary stages of flow is about 300 feet; hence the average fall of the river is about four inches to a mile, or roughly 1 : 18,000. The average fall of the flood plain is about twice as great as that of the river,

and the lateral slope of the flood plain away from the river is much stronger, being sometimes several feet in a mile. The average radius of the Mississippi meanders is from two to two and a half miles; the crescentic lakes of the flood plain represent the maximum dimensions reached by meanders before they were cut off and abandoned. Between 1825 and 1897 fourteen meanders were cut off, and the river would have thereby been shortened 160 miles, had it not been for compensation in the enlargement of other meanders. The river length therefore varies about an average value; it is always slowly lengthening by enlargement of meanders, and it is occasionally and suddenly shortened by cut-offs.

For thirty years past, engineering works, designed to retard or prevent the change of the river course, to improve its channel, and to dike the bordering lands against overflow during floods, have been in charge of the Mississippi river commission, under direction of the Chief of Engineers, U. S. Army, with headquarters at St. Louis. Annual reports and elaborate maps have been published; these and the river itself we shall see in a boat trip from Memphis, Tenn., where the river swings against the eastern border of its flood plain, to Helena, Ark., where it touches the western border.

PART II. DAILY ITINERARY OF THE EXCURSION

First Day, Thursday, August 22

NEW YORK CITY TO ALBANY AND UTICA

THAT division of the city of Greater New York known as the Borough of Manhattan occupies the terminal part of the Manhattan prong of the older Appalachian belt, which extends southwestward from the broad highlands of New England, between the sea on the southeast and the sandstone lowland strip on the northwest. The end of the prong is low because the peneplain, to which the whole region was once reduced, has here been little uplifted; the prong is narrow, because it is overlapped on the southeast by the sea and limited on the northwest by the near-by lowlands of the red sandstone strip. A short terminal portion of the prong is isolated from the rest by a tidal water passage, Harlem river and its branch, Spuyten Duyvel creek, — names recalling the Dutch settlement of the Hudson, — which connects the North or Hudson river on the west with East river, this name being given to the narrow water channel which joins Long Island sound with New York harbor.

The deformed crystalline schists of the Manhattan prong are well seen in the excavations now in progress for the construction of the Grand Central Terminal of the New York Central railway lines in the heart of New York city. The rock surface is glaciated and occasionally drift covered.

After starting from the Grand Central Terminal, the train

soon turns west near Harlem river and along Spuyten Duyvel creek to the east bank of the Hudson, which is then followed 150 miles northward to Albany. The west bank of the Hudson is here bordered by the Palisades, a rather even-crested ridge maintained on a west-dipping monoclinal sheet of intrusive trap, under- and overlaid by weak sandstones; hence the Hudson here occupies a subsequent valley, excavated along the basal members of the red sandstone strip that is included between the Manhattan and Reading prongs of the crystalline belt. The gradual ascent of the Palisade crest, for nearly forty miles northward from its low emergence southwest of New York harbor to its termination in a knob known as High Tor, and the fair accordance of its growing altitude with that of the neighboring highlands of disordered crystalline rocks may be taken as sufficient evidence of former peneplanation of this district.

North of the curved end of the Palisade ridge — the curve being due to a slight warping of the trap sheet — the Hudson widens in Peekskill bay, a natural result of the smaller dip of the weak sandstones at the northeast end of their strip than along their eastern border. Beyond the end of the red sandstones the Hudson, still navigable, occupies a deep and narrow gorge, limited by the crystalline highlands on both sides and truly fiord-like in appearance; its course is at first transverse, then longitudinal, then transverse again. West Point, the site of the United States Military Academy, occupies a bench on the west side of the gorge; this bench is believed to be a remnant of an earlier valley floor, which is broadly visible in the low upland of the Great Appalachian valley, north of the gorge.

The Hudson here is not a normal river, in the sense that its volume depends on the rainfall over its basin, but an estuary of brackish water, whose navigable volume is maintained by the ocean. Its depth may be due in part to submergence of

a normal valley, in part to glacial scour of such a valley below sea level; if the latter explanation prove to be correct, the gorge of the Hudson might be regarded as a true fiord.

On leaving the gorge in the resistant crystalline rocks and entering obliquely into the folded Appalachian belt, here mostly composed of weak slates and flagstones, the older Appalachian highlands at once give way to the north-south lowlands of the Great Appalachian valley; but in consequence of regional

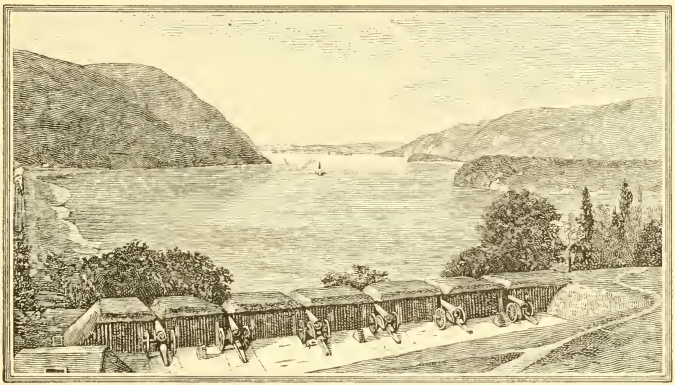

Fig. 18. The Hudson River, looking North from West Point.

uplift, the lowlands should now be called uplands, beneath which the Hudson has intrenched its narrow course. We stop at Fishkill and take an inclined railway to ascend Mt. Beacon, a member of the dissected highlands bordering the Hudson gorge on the east; here we enjoy an extensive view of the gently undulating sky line of the highlands to the southwest, east, and northeast, of the broad floor of the Great valley to the north, west, and southwest, and of its inclosure on the farther side by the escarpment of the mountainous Catskill plateau.

On returning to Fishkill and continuing along the Hudson to Albany, the tilted flagstones and slates of the Great valley are often exposed in railroad cuttings, while the upland surface, west of the river, is seen evenly truncating their upturned edges. Faint tidal changes of water level are still felt in the Hudson, although the water current here is always southward and the water soon becomes potable; numerous ice houses along the river bank testify to an important winter industry. Albany, the capital of New York state, is at the head of navigation. Here we cross the river, and ascend to the surface of a large clay-and-sand delta, deposited in the greater Hudson water body (estuary?) of late-glacial time by the inflow of the Mohawk, then temporarily a vastly larger river than now, because it brought the discharge of the Great lakes while the St. Lawrence outlet was still blockaded by the retreating Laurentian ice sheet. The Mohawk now follows a northern radius of its ancient delta to the Hudson; it is superposed on rock ledges near its mouth, and near the falls thus produced lie the industrial cities of Cohoes and Troy north of our route; at the head of the delta we pass the manufacturing city of Schenectady. The Helderberg escarpment, one of the several steps by which ascent is here made to the mountainous Catskill plateau, is seen to the southwest of the delta plain; it there turns the corner from facing east into the Hudson valley to facing north into the Mohawk valley. Similar but lower escarpments, more or less dissected by obsequent streams, are seen on the south as we ascend the Mohawk valley; the Adirondacks, which rise gradually some distance to the north, cannot be seen because the valley bottom is too deeply incised beneath the broad subsequent depression that it follows.

The value of the tidal and navigable Hudson and the low-grade Mohawk valley as a line of travel and transportation from the ports of the Atlantic coast to the broad prairies of the in-

terior, was early perceived. It was by this pathway that thousands of early settlers from the Hudson valley and the New England States reached the fertile prairie plains, south of the Great lakes. The Erie canal, a state enterprise, was constructed in the first quarter of the nineteenth century from the head of navigation on the Hudson at Albany through the Mohawk valley and beyond to Buffalo at the east end of Lake Erie. It is now paralleled through much of its length by two railways:

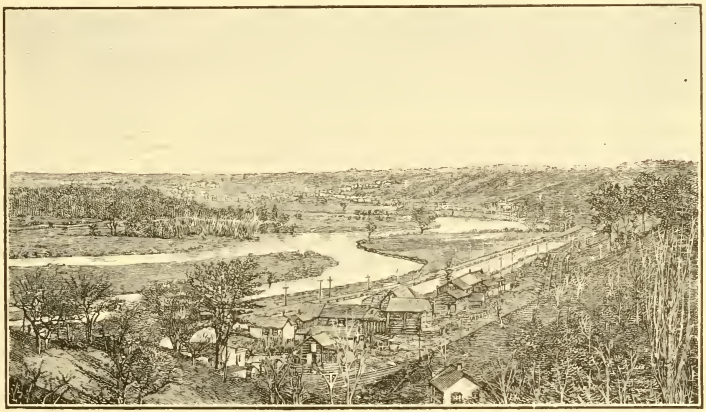

Fig. 19. The Mohawk Valley.

one, the New York Central, which we follow, has four tracks from Albany to Buffalo; the other, the West Shore (so called because of following the west shore of the Hudson northward from New York city) with two tracks, is seen on the south side of the Mohawk valley, while we take the north side from Schenectady to Little Falls. A new waterway, the Barge canal, 75 feet wide and 12 feet deep, is now under construction by the state for vessels of large tonnage; we see the work in progress or lately finished at many points. The traffic along the Mohawk

may therefore be compared with that which follows the gorge of the Rhine.

The most peculiar topographical features of the Mohawk valley are dependent on the occurrence of transverse faults with uplift on the west, whereby the underlying crystalline rocks are raised so high that they are now laid bare by erosion. The valley is maturely opened on the weaker strata, with a flood plain on which the river freely meanders — the breadth of the valley floor being, however, more probably the work of the enlarged Mohawk in late-glacial time than of the present reduced stream — but wherever the river is superposed on the crystalline rocks, the valley is at once reduced to smaller width. The uplands maintained on the crystalline rocks are terminated at each fault by a well-defined east-facing escarpment, because the weaker strata which formerly abutted against the crystallines are now broadly removed; hence these scarps should be called "fault-line scarps," as due to erosion acting on a faulted mass, and not "fault scarps," a term which should be restricted to scarps now more or less dissected, but initially produced directly by faulting. Where the first of the stronger fault-line scarps is breached by the Mohawk, the bold headlands on either side of the valley are known as the "Noses." A little farther west, after the uplifted crystallines have disappeared, a fine postglacial gorge has been eroded in the weak overlying shales on the south side of the valley, and at its mouth lies the village of Canajoharie. Farther on, another fault-line scarp is breached by the narrowed Mohawk, which is there beset with ungraded rapids; here the manufacturing city of Little Falls has grown. We turn back for a mile on a branch line, to reach the crest of the scarp and enjoy a view down the Mohawk valley. Then returning to the main line we have a short run up the widening valley to Utica, where we spend the night.

Second Day, Friday, August 23

UTICA TO SYRACUSE AND ITHACA

We make an early start from Utica, and soon reach Syracuse. The Mohawk valley continues to widen above Utica, and at Rome — these being some of the many towns to which classical names were inadvisedly applied at a time of hurried baptism a century ago — we cross the broad, flat lowland divide between the Mohawk-Hudson and the St. Lawrence basins. From this point westward the lowland, sloping gently northwest to the basin of Lake Ontario, was for a time covered by a great glacial-marginal lake, held in when the retreating Laurentian ice sheet obstructed the St. Lawrence valley; it was this lake — to which the Indian name, Iroquois, has been given — which received the waters of the other Great lakes farther west at the time when Niagara falls were initiated, and which supplied the great volume of outflow that flooded the late-glacial Mohawk and built the high-level delta by Albany. The shore lines of the lake, faintly developed in the narrow and shallow waters near the outlet, become increasingly distinct farther north and west where the waters were wider and deeper.

As we advance farther westward, distant views of the border hills of the Adirondacks are obtained to the northeast. Near by on the south is the northern margin of the Appalachian plateau, sometimes possessing a relief of 800 or 1000 feet, abundantly dissected into spurs and hills by the obsequent valleys of south-north streams; and from this margin the broken country of the plateau is continuous for 800 miles southwestward to northern Alabama, where we shall cross its southern end on our return journey.

At Syracuse we make a local excursion southeastward into the hills of the plateau border, to see two examples of channels and

plunge-pool lakes scoured out by the temporary, late-glacial, east-flowing Niagarawk river (see p. 21), which took its spasmodic course across the plateau spurs, following the variable depression defined by the fixed northward slope of the plateau margin and the shifting southward slope of the retreating ice sheet. The lakes are of little importance in themselves, but they are remarkable witnesses to extinct conditions of drainage, which have left many significant marks in this district. The origin of the channels and lakes was first explained by Gilbert; many examples occurring in this district have been described by Fairchild.

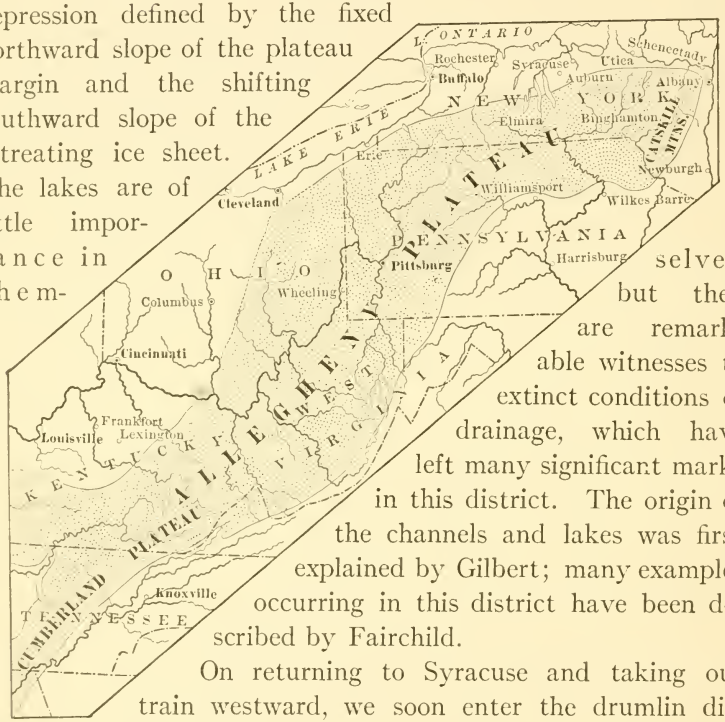

Fig. 20. The Appalachian Plateau.

On returning to Syracuse and taking our train westward, we soon enter the drumlin district of central New York, which occupies a part of the confluent Ontario-Erie lowland, here not divided by the Niagara escarpment; this feature does not make its appearance for some fifty miles farther west. The drumlins have been studied by Fairchild, who estimates their number at several thousands; they are more elongated than the drumlins of New England; they are locally parallel to one another, but as a whole exhibit a slight divergence to the southeast,

south and southwest; they completely dominate the topography of their district. Roads, property lines, fields, and houses are all oriented with respect to the major axes of these elongated hills. Not far north of our route, the drumlins are cliffed and connected by gravel reefs, the work of the waves of the late-glacial Lake Iroquois, the outlet of which enlarged the valley of the Mohawk.

The drumlins are interrupted for a short distance by the Montezuma marshes, which occupy the shallow northward end of the trough-like basin of Cayuga lake, to be seen later in the day. Beyond the marshes, the old Erie canal, the new Barge canal, two steam railways, and a new electric railway all follow abandoned waterways eroded through the drumlin belt by late members of the glacial-marginal drainage system.

At Lyons we make a detour southward, in order to see Cayuga lake, one of the several Finger lakes, which occupy glacially deepened north-south troughs between coarse-textured plateau spurs of moderate relief. We turn first south to Geneva; then southeast across a broadly convex plateau spur, until the trough of Cayuga lake comes into sight between this spur and the next one on the east. A stop is made at the head of a gorge into which a lateral stream plunges in Taghannock falls. A little farther on, Ithaca stands on the delta plain at the head (southern end) of the lake. We ascend to the grounds of Cornell University, on the upland of the spur east of the lake trough, for the late afternoon hours. The simple form of the smooth spur sides and the hanging attitude of many side valleys, from which the streams of the upland descend through sharp-cut ravines with many falls to the lake, are accepted by most observers as indicating strong glacial erosion in shaping the lake basins. No valleys of similarly simple form are found farther south, in the non-glaciated parts of the Appalachian plateau. During

the retreat of the ice from the Finger lakes, the local proglacial lakes had southward outlets through the plateau country to the Susquehanna and other rivers in Pennsylvania. The open channels cut through preglacial passes by these temporary but vigorous outlet rivers are characteristic features near the Pennsylvania-New York boundary.

In the evening we take our train, return to Geneva, and go on to Rochester.

Third and Fourth Days. Saturday and Sunday, August 24 and 25

ROCHESTER TO BUFFALO AND NIAGARA

Those who rise early may see the falls and gorge of the Genesee river, close to the station in Rochester. The falls are upheld by the Niagara limestone, which from here westward assumes topographic importance and forms at first a low bench, rather than a cuesta, separating the Ontario lowland on the north from the somewhat higher Erie lowland on the south. Genesee river, flowing northward from among the plateau hills across the Erie lowland, has cut a gorge several miles in length in the gentle slope by which descent is made from the cuesta-bench to Lake Ontario. At the head of the gorge, the falls plunge into a large amphitheater, around which the city is built on the upland.

The morning run to Buffalo leads across the broad drift-covered plain of the Erie lowland; kames and kettles are passed near Batavia; a gravel-ridge beach of a great proglacial lake near Crittenden; and the plain of the lake bottom is then crossed to Buffalo. The gentle ascent to the Appalachian plateau, which has here lost its strength of expression, is seen some distance to the south.

At Buffalo, we see the harbor on the lake front — the western

end of the Erie canal and the eastern end of Lake Erie — and visit the Lackawanna Steel Works; these are supplied with coal brought by rail from western Pennsylvania, and with ore from the iron range in northern Minnesota, transported on lake boats. At noon our train carries us northward, roughly parallel to Niagara river, and we thus reach the city of Niagara Falls, where we pass the afternoon and the next day.

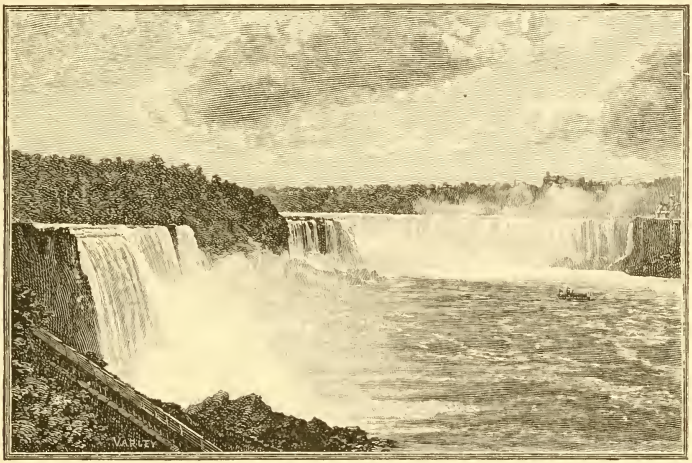

FIG. 21. Niagara Falls.

During our visit to Niagara, the features that chiefly deserve attention are: The rock structure as shown in the walls of the gorge below the falls; namely, strong limestones on weaker shales and sandstones, all dipping gently southward, and belonging to the great series of strata that form the ancient coastal plain in relation to the Laurentian oldland of Canada. The broad and nearly level upland of the cuesta maintained by the resistant limestones, ending to the north in a well-defined escarpment, beneath which the inner lowland slopes gently to

the basin of Lake Ontario, visible in the view north from the rim of the scarp. The even margin of the escarpment, exceptional in normal cuestas of very gently dipping strata, and presumably due here to glacial erosion; the oblique southwestward movement of the ice sheet seems to have scoured off the normal irregularities of the cuesta front. The vast erosion necessary to excavate the inner lowland by normal erosion in preglacial time, supplemented by glacial erosion. The abandoned beach of one of the great proglacial lakes — Iroquois — beneath the escarpment on the American side of the lower Niagara river, back of Lewiston. The sharply cut gorge, from its beginning in the escarpment back to the present falls. The great height of the initial falls on the escarpment front. The rapid retreat of the falls under the action of a large river, compared to the slow retreat of the escarpment and of the gorge walls under the attack of the atmosphere. The rapid deepening of the gorge by the river, compared to the slow work of small side streams in deepening their courses, which hang high over the gorge bottom. Wintergreen flats, on the Canadian (west) side of the gorge below the Whirlpool, where the retreating falls were temporarily divided into a larger American and a smaller Canadian fall — the reverse of the condition at Goat island between the present smaller American and larger Canadian falls. The Whirlpool, where the gorge seems to have been cut back into a drift-filled pre- or interglacial obsequent ravine. The narrowing of the gorge upstream (south) of the Whirlpool, believed on good grounds to be due to the temporary diversion of the waters of the upper Great lakes from Lake Huron and Georgian bay direct to the lower St. Lawrence river, when the ice sheet had sufficiently retreated across the province of Ontario and while the land was lower to the north; thus leaving Niagara river to be fed for a time only by Lake Erie: had this condition per-

sisted and the Great lakes outlet served, as it does now, to mark the international boundary between the United States and Canada, all the fertile agricultural region in the southwestern part of what is now the province of Ontario, which closely resembles western New York state, would have been lost to the British provinces. The location of the two railroad bridges at the narrowest part of the Niagara gorge. The increase in the width of the gorge farther upstream, explained by the return of the drainage from the upper lakes to its passage through Lake Erie, when the elevation of the land in the northeast raised the temporary channel across the province of Ontario to a greater altitude than the channel by Detroit; thus the present detour of the Great lakes outlet cuts out a part of the Niagara cuesta with its adjacent parts of the inner and outer lowlands from the United States, and brings this southernmost point of the Dominion of Canada, which so deeply indents the northern boundary of the United States, about 300 miles farther south than it would otherwise have been. The drowning of the lower Niagara to navigable depth in its course from the escarpment across the lowland to Lake Ontario, because of the continued rise of land to the far northeast. The great plunge pool below the falls, where the depth of water is about the same as the height of the falls. The small retreat of the American falls compared to the rapid retreat of the Canadian falls, the latter being estimated to be at present about four feet a year in the central "Horseshoe" falls; hence the eventual withdrawal of all the water from the American falls, so that Goat island will be a large example of Wintergreen flats. The fine view of the upper rapids, the falls, and the gorge from the drift terrace west of the Canadian falls. The diversion of water from the river above the falls to lateral canals and tunnels for use in developing electric power stations, and associated industrial plants.

Fifth Day, Monday, August 26

ASHTABULA TO CLEVELAND, TOLEDO, AND DETROIT

After a night run from Niagara and Buffalo and along the southern border of Lake Erie, we see in the early morning the lake to the north, and to the south the weakening northern margin of the Appalachian plateau, which is now losing height preliminary to its confluence with the drift-covered prairie plains. We run near the gently ascending southern border of the Erie lowland, between the lake and the plateau margin, which is here occupied by a lacustrine coastal plain, in the sense that it is covered with stratified clays, the deposit of vanished proglacial lakes. The plain was laid bare, not by the elevation of the land as in the case of marine coastal plains, but by the withdrawal of the proglacial lake waters when the northward retreat of the ice sheet opened lower and lower lake outlets. Young shore lines, formed on the plain during pauses in the withdrawal of the lake, may be recognized from the passing train. Numerous streams, following consequent courses from the plateau, which represents the oldland, across the coastal plain to the lake, have eroded narrow valleys of early mature form; the lake waves have cut a cliff, which gives the present shore line a much more mature expression than any earlier one; but the plain as a whole remains young and undissected back of the cliff and between the valleys. Ashtabula, at the mouth of one of the consequent valleys, is an important lake port, receiving iron ore by lake boats from Minnesota and shipping it to Pittsburgh by rail. The significance of this port is not especially due to its local advantages, for it has no natural harbor, but rather to its lying nearer than any other lake port to Pittsburgh. In recent years from 6,000,000 to 9,000,000 tons of ore have been received here

annually, chiefly for shipment to smelting furnaces in the coal fields of western Pennsylvania.

The plateau on the south gradually disappears and the lacustrine plain broadens. One of the numerous consequent streams that has eroded a mature valley in the plain is the Cuyahoga; at its mouth and on the adjoining plain lies the active industrial city of Cleveland. We go on westward across the plain to Elyria, to visit a series of abandoned shore lines: the highest of them belonged to a local proglacial lake that had its outlet southwest of the present Lake Erie to the Ohio river (see below); the lower ones belonged to Lake Warren, a great proglacial water body which had at first an outlet by Chicago southwestward to the Mississippi, and later, eastward to the Hudson. All of these shore lines ascend a few feet in a mile to the northeast, thus indicating a postglacial uplift of the continent in that direction. None of the shore lines are of nearly so advanced a stage of development as the existing mature shore line of the present lake. We see on the way the incised meandering valleys of several mature consequent streams.

On returning to our train and continuing westward we regain the outer border of the lacustrine coastal plain. The waters of the lake invade some of the valleys, slightly at first, more broadly farther on, because of the rise of the land to the northeast since the disappearance of the ice sheet. Thus bays are formed in the southwestern part of Lake Erie, on two of which are the cities of Sandusky and Toledo. Southwestward from the latter city, the abandoned shore lines of the highest proglacial lake converge to a faint depression in the height of land; there the lake outlet overflowed and cut a shallow channel across the till sheet of the prairie plains on its way to the Ohio river.

At Toledo we take a steamboat to cross the western end of Lake Erie and ascend Detroit river to the city of that name,

where we spend the evening. The navigable depth of Detroit river, a factor of great importance in the shipment of iron ore from the northwest and of coal to the northwest, is due, like the embayments at Sandusky and Toledo, to the modern rise of the land in the northeast, whereby the trench cut in the plain by the former river is now drowned.

Sixth Day, Tuesday, August 27

MICHIGAN CITY TO CHICAGO

During the night our route lies across the drift-covered lowlands near the southern border of the "lower peninsula" of Michigan; in the early morning we reach Michigan city, at the southeastern side of the lake of the same name. This large lake once had a greater extension to the south; but the formation of successive sand reefs around its concave southern end and the filling of the shallow inclosed lagoons by marshes have somewhat reduced its size. Large sand dunes have been formed on the reefs, as at Michigan city.

We follow around the southern end of the lake at a varying distance from its shore, and thus approach Chicago. When the northward discharge of Lake Michigan was obstructed by ice, its outlet ran across the prairies to the southwest, and excavated the channel now followed by the Illinois river to the Mississippi. The deepening of the channel near the lake was delayed by a sill of resistant limestone. When the northward outflow of Lake Michigan was established, the divide between the lake and the Mississippi system crossed the dry outlet channel near the lake. The Indians and the early "voyageurs" there had a "portage" for their canoes; there a military outpost, Fort Dearborn, was established early in the nineteenth century, and there the city of Chicago began its precocious growth. To-day

the channel has been artificially deepened, so as to restore in part the ancient outflow, and thus dispose of the sewage of Chicago, which was until recently discharged into the lake. This was unsanitary, as the water supply of Chicago is taken from the lake by a tunnel from beneath a " crib " about a mile from shore. The impure waters now turned by the drainage canal into the Illinois river are so far purified by natural processes that St. Louis gets an excellent water supply from the Mississippi below the mouth of the Illinois, as we shall see during our visit to that city. Chicago river, enlarged to navigable depth by rise of land to the northeast, had become a foul and stagnant water channel before the opening of the drainage canal, but is now traversed by a gentle current of pure water.

We spend the day in Chicago, and in the evening take train for Madison, Wisc.

Seventh Day, Wednesday, August 28

MADISON TO LA CROSSE, WISC.[1]

We approach Madison in the early morning through the drumlin district that occupies much of the area covered by the Green bay glacial lobe. At Madison, we visit the grounds of the State University, seeing two small Indian mounds on a glacial hill, and gaining a general view of the lakes that adjoin the city. We then make a local excursion westward across part of the glaciated area of the Green bay lobe, first passing two recessional moraines and then the terminal moraine, beyond which we enter the Driftless area of normal erosional forms, here characterized by a maturely dissected bench or cuesta formed by a low limestone member of the ancient coastal plain series. We return to Madison by another road, farther north, and review the same features.

[1] Based on notes by Professor L. Martin, of the University of Wisconsin.

At noon we take train at Madison and run an hour northward to Devils lake in Baraboo ridge. This ridge is an ancient monadnock of quartzite, which surmounted the peneplain that was worn down on the fundamental crystalline rocks previous to the deposition of the ancient coastal plain strata south of the Laurentian region. The monadnock was buried in these strata and thus preserved — a true geographical fossil — for ages, until in relatively modern times it was laid bare by the erosion which produced the Niagara cuesta and the lowlands of the Great lakes.

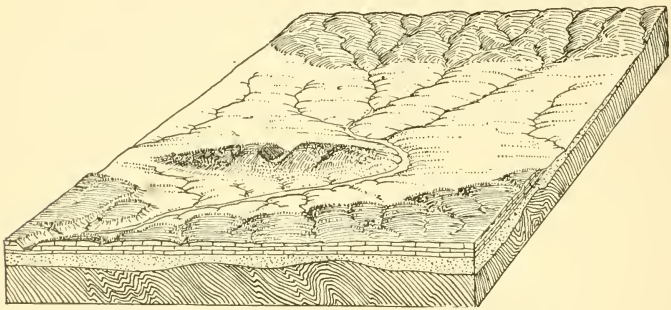

FIG. 22. Diagram of Baraboo Ridge, Wisconsin.

The western moraine of the Green bay lobe crosses Baraboo ridge near the point where we stop; thus the eastern part of the ridge has been ice-scoured, but not the western part. Through the middle of the ridge is a deep notch, in which lies Devils lake; we ascend the bluff east of the lake for a general view of the district. On descending to the north, we pass over some of the conglomerate beds which were formed during the ancient submergence of the region, when the ridge was for a time an island.

On taking the train again, we soon pass the terminal moraine and then continue in the Driftless area for the rest of the day. Some miles farther on we make a brief stop at Camp Douglas, to ascend a sandstone outlier, isolated from the low bench formed

by the non-dissected sandstones, farther southwest; it gives us a view over the innermost lowland towards the stripped foundation of resistant crystalline rocks which now form the highlands of northern Wisconsin. From Camp Douglas we turn westward, and during the early evening pass another one of the low cuestas which partly encircle the Wisconsin highlands, and at La Crosse reach the Mississippi river.

Eighth Day, Thursday, August 29

LACROSSE, WISC., TO ST. PAUL AND MINNEAPOLIS, MINN.

In the early morning we follow up the east side of the broad channel, incised here through the Driftless area by the enlarged Mississippi of late-glacial time, and now occupied by the present, normal, underfit Mississippi. We enter the glaciated area before reaching Lake Pepin; there we stop for an ascent of the bluffs to the prairie level, whence we obtain a general view of the broad channel, and especially of the lower end of Lake Pepin, a long expansion of the Mississippi to the whole breadth of the channel floor. This singular feature is due to the aggradation of the channel floor by the Chippewa, a tributary which comes from the northeast and which was at one time so heavily charged with waste that its deposits could not be swept away even by the Mississippi, and the lake resulted.

We descend to the train, and follow up the border of Lake Pepin to its head, where the misfit Mississippi again wanders on the channel floor. Farther on we pass the tributary valley of St. Croix river, coming from the north, and here forming the boundary between Wisconsin and Minnesota, which has been marked by the Mississippi farther south. Here the Mississippi has aggraded the channel floor, and a slender lake occupies the St. Croix valley.

St. Paul, the capital of Minnesota, occupies the upland on the northeast of the Mississippi, at the head of navigation. Here we pass through the city to visit the confluence of the Mississippi and the Minnesota at Fort Snelling, a few miles to the west. The Minnesota, the smaller river of the two, comes from the west and northwest, strikingly underfit, along the great channel that was eroded in late-glacial time by River Warren, the outlet of the great proglacial Lake Agassiz. The Mississippi, the larger river, comes from the north in a gorge of its own postglacial erosion, at the head of which, a few miles upstream, are the Falls of St. Anthony, and there the manufacturing city of Minneapolis has grown, famous for its flour mills, and now the seat of the State University.

During the erosion of the gorge, the Mississippi was divided into two channels, inclosing an island, about midway between Fort Snelling and Minneapolis; the eastern channel was the larger of the two and had cut its gorge back to the point of bifurcation; the waters were then withdrawn from the western channel, in which much less progress in gorge cutting had been made. A small stream fell into this unfinished gorge from the west, and has now cut a little gorge of its own, at the head of which is a small cascade, the Falls of Minnehaha. In the afternoon we visit Minneapolis, and in the evening go on to Duluth.

Ninth and Tenth Days, Friday and Saturday, August 30 and 31

DULUTH AND THE IRON DISTRICT OF MINNESOTA[1]

The night ride northeastward from St. Paul carries us across the glaciated highland peneplain of east-central Minnesota; we see something of the same country in our ride to-day from Duluth

[1] Based on notes by Professor N. H. Winchell, formerly state geologist of Minnesota.

northward to Hibbing in the Iron district. This entire region is a southwestward extension of the Laurentian highland of Canada; it consists of greatly deformed rocks, for the most part of crystalline texture, and has been as a whole reduced to moderate relief; but it is here and there surmounted by subdued hills and ridges, standing singly or in groups or ranges; it has been scoured by the Canadian ice sheet, whereby the preglacial inequalities of the surface have probably been decreased in so far as the rock hills lost some of their height, and increased in so far as shallow basins were excavated in areas of weaker rocks; abundant deposits of drift were strewn over the surface either as sheets of till or as morainic hills, whereby the preglacial drainage of the district was thrown into disorder; the streams of to-day exhibit all the features of a new youth, as they hesitate in countless lakes and swamps where they wander on the drift-covered surface, or hasten in rapids and cascades where they are superposed on rock ledges. The short streams that drain into Lake Superior have a strong descent in their lower courses, where they descend several hundred feet from the slightly dissected highland to the lake level.

After leaving Carlton, about 30 miles west of Duluth, we descend from the ancient rocks of the highland to a covering of lacustrine clays, deposited in a shallow western extension of the Lake Superior trough from the waters of a proglacial lake which had a southward discharge to the St. Croix river, the junction of which with the Mississippi we saw shortly before reaching St. Paul. This embayment is now drained by the St. Louis river, which comes from the highland on the north, descends by falls into the embayment, and then flows eastward to the western end of Lake Superior, known as St. Louis bay. We run down by easy grade from the highland at altitudes of 1200 feet along the clay-covered embayment to the present lake at an altitude

of 600 feet, and there see that St. Louis bay is inclosed by a huge north-south sand reef formed by one of the early proglacial lakes, and now standing well above the actual lake surface. We follow the southern shore of the bay, thus entering Wisconsin, and reach the city of Superior; there we return into Minnesota by following the sand reef to its northern end at Duluth.

After a short halt we continue our journey, first following near the lake shore, then turning inland and ascending the drift-covered slope of the highland to the northwest by a strong grade. Shore lines of proglacial lakes have been traced along this slope, and all of them show a gradual ascent to the northeast: one of the shore lines emerges from beneath the present lake waters a few miles east of Duluth; its concealed part has been drowned by the rise of the western lake waters in consequence of the uplift of the continent to the northeast. For the same reason the streams that enter the lake hereabouts are all drowned near their mouths. Occasional embayments in the rock slope of the highlands, apparently of normal erosional origin yet too large for postglacial erosion, suggest that the deep basin of Lake Superior is of preglacial origin; it has been explained by down faulting, but without full demonstration as yet.

After the ascent from the lake margin, we cross the highlands over heavy and abundant drift deposits with many lakelets and swamps, which cover the rock surface over large areas. We thus reach a belt of country named the Mesabi iron range from its ore deposits, not from its relief, for it is gently undulating; farther on is the Giants range, a belt of granitic hills that rise several hundred feet over the highland; and back of this is the Vermillion iron range. We cross the headwaters of St. Louis river on the way. At Hibbing we visit two of the mines; the ore being "soft," it is excavated by steam shovels from huge open pits. The extensive development of the mines in the last

25 years has attracted a large population into a wilderness that otherwise has very limited resources. The wholesale working and enormous dimensions of the ore pits in the highland and the ingenious devices for rapid shipment of ore at Duluth deserve attention. Return to Duluth is made in the late afternoon and early evening.

On Saturday morning we are invited to make an excursion from Duluth by steamboat across St. Louis bay to Fond du Lac and a new steel plant. In the afternoon we see something of Duluth, a significant feature being a boulevard that follows an ancient lake shore line on the slope of the highland northwest of the present lake and 650 feet above its waters. In the late afternoon, we resume our journey by train, returning past Superior and Carlton, thence continuing westward across the highland, and crossing the upper Mississippi at Brainerd in central Minnesota late in the evening.

Eleventh Day, Sunday, September 1

DETROIT, MINN., TO BISMARCK, N.D., AND BEYOND[1]

During the night we have crossed the drift-covered highland peneplain of north-central Minnesota, and in the early morning find ourselves on the eastern border of the treeless Great plains, where weak stratified deposits, dipping very gently to the west, lap upon the slanting highland floor of the resistant crystalline rocks. We descend into the so-called Red river valley, a broad subsequent depression, here about 40 miles wide, which has been eroded on weak basal strata, between the crystalline highlands on the east and a gentle rise of stronger strata on the west, known as the Manitoba escarpment. The valley is now covered with a smooth sheet of till, made yet smoother by a cover of silts de-

[1] Based on notes by Professor H. E. Simpson, University of North Dakota.

posited from the waters of the great proglacial Lake Agassiz, of which we saw the outlet trench at Fort Snelling, near St. Paul. The highest eastern beach of the lake is passed near Muskoda. We descend by a long, straight track on an embankment, from which extensive views are offered to the north and south. The Red river, a typical young consequent stream, flows northward through the axis of the valley plain in a narrow, intrenched meandering valley of small depth. Consequent tributaries are seen on the east and west in Buffalo and Cheyenne rivers. Vast stretches of the plain are undissected; here the water often lingers doubtfully after thaws and heavy rains, undecided as to the direction of run-off.

At Red river crossing we pass the competitive cities of Moorhead, Minn., and Fargo, N.D., in the quiet of Sunday morning. The fertility of the lacustrine silts has made the valley a wheat-growing region: property is often held in vast farms comprising thousands of acres; farming is done in a wholesale manner; the sale of agricultural machinery is an important preparatory industry. Beyond Casselton and Wheatland, in the western half of the plain, we pass several abandoned shore lines, and then ascend the slope of the Manitoba escarpment; but the ascent is so gradual that our track is still straight. The escarpment extends far northward into Canada, with increasing relief; to the south it weakens and is known as the Coteau des Prairies.

After ascending the scarp, we cross a broad, drift-covered upland of gradually increasing height. Irregular moraines mark pauses in the retreat of the ice sheet from its greatest advance many miles farther southwest on the Great plains. Large channels, occupied by underfit streams, represent the work of late-glacial rivers, fed from the retreating ice sheet. The first one of these, drained by Cheyenne river, we cross on a superb viaduct, and look down on Valley city on the channel floor. A

few miles east of this channel a low cuesta, with ragged front and outliers, is determined by the outcrop of more resistant strata on the peneplain to which this whole region was reduced in preglacial times. Other channels little farther west have been obstructed by later morainic deposits, and now hold long lakes or strings of lakes; we cross the middle of Eckelson lake, the longest of the group. Farther on is another channel, drained by James river, and occupied on our line by Jamestown, to and from which we descend and ascend on our westward course. Some ten miles west of Jamestown, we cross the strongest escarpment of the region, the Coteau du Missouri; then we descend by an open depression to the broad valley of the Missouri river at Bismarck, the capital of North Dakota. It is noteworthy that the uplands on either side are here much more elaborately dissected than was the case with the uplands bordering the trench followed by Cheyenne river.

After crossing the Missouri, we follow the lateral valley of Heart river westward, and gradually reach the upland peneplain. Glacial drift is here inconspicuous as a topographic element. Occasional residual hills attest the erosional origin of the plain, which we traverse until nightfall.

Twelfth Day, Monday, September 2

IN THE BAD LANDS OF THE LITTLE MISSOURI

The morning finds us on the Great plains, which are becoming more and more arid. On approaching the north-flowing Little Missouri, the upland peneplain of the former cycle of erosion becomes more dissected, and we soon descend into the valley of the present cycle at Medora. We here make an all-day wagon trip, during which a large variety of characteristic bad-land features will be seen, including ragged escarpments that sur-

mount the peneplain of the region, and minutely dissected valley sides that are intrenched below it; we visit a cattle ranch in the afternoon. Towards evening we return to Medora and take our train westward, ascending from the valley and again traversing the Great plains after dark.

Thirteenth Day. Tuesday, September 3

LIVINGSTON, MONT., TO THE YELLOWSTONE NATIONAL PARK

During the night the railroad reached the valley of the Yellowstone, into which it has descended from the plains. The dissected valley sides give abundant exposures of the nearly horizontal strata of the region, little covered with vegetation. As we approach Livingston, the maturely dissected Crazy mountains may be seen to the north; they are composed of essentially horizontal strata of the plains series, traversed by numerous dikes, to which their survival is due. They indicate in the most striking manner the enormous erosion accomplished in the general peneplanation of the neighboring Great plains region.

At Livingston we turn south, and soon enter the lower canyon of the Yellowstone, where it has trenched the hard, upturned rocks of the Rocky mountain front, which here has a local turn from east to west. The most important mountain-making strata here are heavy and resistant limestones, dipping to the north. Their attitude gives the impression that the altitude of the mountains above the neighboring plains is due to upheaval: as a matter of fact, the excess of altitude is due to their hardness, which has enabled them, except where trenched by streams and rivers, to preserve a large measure of the elevation gained by regional uplift after the whole region had been subdued; while the neighboring weaker strata have lost their elevation in reduction to the vast peneplain of the Great plains. This illus-

trates the difference between "age" and "stage"; the steep-walled canyon cut by the Yellowstone in the hard limestones is of the same age, measured in years, as the peneplain, which has been worn down by general weathering and washing on the weak strata of the plains; but the canyon is still in an early stage of its cycle of erosion, while the plains are in a late stage of theirs: the canyon is in a young stage, while the plains are in an old stage of development, although they are of essentially the same age. The distinction here made was concisely stated by Kant, who wrote: "Wenn man wissen will, ob ein Ding alt, ob es sehr alt, oder noch jung zu nennen ist, muss man es nicht nach der Anzahl der Jahre schätzen die es gedauert hat, sondern nach dem Verhältnis, dass diese zu derjenigen Zeit gehabt haben, die es dauern sollte."

Upstream (southwest) from the canyon the valley broadens, as if the rocks were less resistant; but its breadth is possibly due to down faulting. The latest lava flows in the district are seen in the valley, 15 or 20 miles above the canyon. No detailed physiographic account has yet been prepared of the adjoining mountains; but the topographic map strongly suggests the occurrence of an uplifted and dissected peneplain, its highlands standing at altitudes of about 10,000 feet. This inferred peneplain must truncate the upturned strata of the mountain front; hence it seems necessary, as above implied, to regard these mountains as belonging in the growing class of two-cycle forms; the first cycle, introduced by strong deformation, having reached old age before the second cycle was introduced by widespread elevation with more or less warping and faulting. Thirty miles above the canyon, the valley turns to the southeast and narrows, thus continuing 17 miles to the railroad terminus at Gardiner. Here we take stage to Mammoth hot springs in the Yellowstone national park.

Fourteenth to Eighteenth Days, Tuesday to Sunday, September 3 to 8

IN THE YELLOWSTONE NATIONAL PARK

A description of the Yellowstone national park, where we stay until our nineteenth day, is provided in the pamphlet issued by the Department of the Interior, of which a number of copies will be placed at the disposal of our Excursion party.

Nineteenth Day, Monday, September 9

YELLOWSTONE NATIONAL PARK TO BOZEMAN, MONT.

We make an early start from the Canyon hotel, return to Mammoth hot springs, and then by stage and train to Gardiner and Livingston. There our westward journey is resumed on the main line of the Northern Pacific railway. The Rocky mountain front, which south of Livingston makes a turn to the west, soon takes its prevailing northward course again, sharp folding and faulting occurring in the reëntrant thus formed. Its northward continuation forms the Bridger range, in which the mountain-making limestones stand about vertical and produce a rather narrow and serrate crest. The strata of the plains are sharply upturned and greatly worn down in subdued forms for several miles east of the range; to the west the resistant crystalline mass of the mountain foundation sinks into the Bozeman basin, an excellent example of an aggraded intermont basin produced by the warping which introduced the second cycle of erosion in the Rocky mountain system. We ascend a subsequent valley west of Livingston to a tunnel beneath Bozeman pass in the foothills of disturbed plains strata; then descend westward to the basin through a canyon in the upturned limestones; so that the mountain front is here drained by a stream, Meadow creek, which flows against the uplift of the

strata: it is probably consequent on the warping of the second cycle.

The broad Bozeman basin is drained by Gallatin river, which with Madison and Jefferson rivers form the three headwaters of the Missouri. The Gallatin has eroded a broad floor beneath the bench land of the earlier basin deposits. At the northern side of the basin, where the three rivers unite in the north-flowing Missouri, the strongly folded mountain-making limestones and associated strata are reduced to small relief, and together with the resistant crystalline mass of their foundation, all of which elsewhere rise in mountain crests, descend beneath the horizontal deposits which cover the basin floor, a behavior that is highly characteristic of a two-cycle mountain system. Some distance to the north, the Missouri, after traversing other basins, makes its escape to the plains by a deep and narrow gorge in the Front range.

Twentieth Day, Tuesday, September 10

BUTTE, MONT., TO SPOKANE, WASH.[1]

In the early morning we cross the continental divide between a branch of Jefferson river, which belongs to the Missouri-Mississippi system, and Deerlodge river, which belongs to the Columbia system. The divide is here formed by the crest of what seems to be a tilted block of granite, which had been reduced to low relief in the previous cycle of erosion, and which now, after uplift so as to present a long slope to the east and an abrupt fault scarp to the west, is submaturely dissected in the present cycle. We ascend the long eastern slope by many curves, and descend the western scarp by sidling along it to the north. The descent leads us to the city of Butte, famous for its copper mines; here we make a brief stop.

[1] Including notes by O. E. Hershey, of Kellogg, Idaho.

On resuming our journey, we follow the valleys of Deerlodge, Hellgate, and Missoula rivers in a generally northwestward direction, through a region for which no detailed physiographic accounts have yet been published. The valley is at first open; below Drummond, it narrows; at Missoula it opens again, and here it has been occupied by a late-glacial lake, the shadowy shore lines of which are seen at many levels on the mountain slopes southeast and east of the city. At Missoula, Bitterroot river comes from a broad "valley" or intermont depression on the south, which, like many other depressions hereabouts, seems to be more the product of deformation than of erosion; it is inclosed by a subdued range on the east, and by the more Alpine Bitterroot range on the west, which here divides Montana from Idaho. This range appears to be a maturely dissected fault block; its valley heads were glaciated, its peaks were sapped and sharpened by the excavation of cirques, and large moraines were deposited forward from the overdeepened trough mouths in the broad valley at the eastern mountain base. The Bitterroot valley has been much aggraded by waste, chiefly from the higher range on the west; it is celebrated for its apple farms on the irrigated "bench land" of early glacial deposits, below which the river has eroded a mature pathway in the valley filling.

We follow the Missoula valley through a mountainous region, in which forest fires have caused terrible loss of timber, the great fire of 1910 having been especially destructive in this district. In the late afternoon we leave Montana and enter Idaho; we then pass around the northern border of Lake Pend d'Oreille, the origin of which, like that of Lake Cœur d'Alene farther south, is presumably associated in some way with glacial action. We then cross the western outlet arm of the lake, and run southwestward to Spokane, on the western border of the mountains, in the early evening.

Twenty-first Day, Wednesday, September 11

SPOKANE TO COULEE CITY, WASH.

Our train leaves Spokane about midnight and carries us across the treeless lava plateau country, on which the morning opens. The surface is rolling; it is here to be regarded as in great part a peneplain produced by long-continued erosion of a deformed surface; for the lava flows, usually horizontal, are here and there interrupted by strong monoclinal flexures, which are now reduced to a small residual of their initial relief. The region is subarid; dry farming is practiced here, as there is no water now available for irrigation over a large part of the plateau. At Coulee city we make local excursions in the morning and afternoon: in the morning a short distance northeast to see a reduced monoclinal flexure, across which the upper course of the Columbia river, temporarily diverted to this path by glacial obstruction of its northwestern "big bend," cut a well-graded channel or "coulee"; in the afternoon a short distance southwest to see the lower course of the same temporary river, where it has eroded a canyon in horizontal lava beds; the head of the canyon was the site of a superb cataract of complicated form; beneath the cliffs at the head of the canyon, small plunge-pool lakes remain, which remind us of the Green lakes of similar origin which we saw on our second day, near Syracuse, N.Y. Several linear lakes occur farther down the canyon, probably due to the irregular aggradation of its floor by lateral inwash. Moses coulee, in the lava plains some twelve miles to the northwest, may be similar in origin to Grand coulee, cut at a lower level and later date.

In the late afternoon we take our train again and turn southward across the lava plateau, and in the night cross the Columbia river at Pasco.

Twenty-second and third Days, Thursday and Friday, Sept. 12 and 13

NORTH YAKIMA TO SEATTLE, WASH.[1]

From Pasco on the Columbia river our route turns northwest up the valley of Yakima river, through the westernmost part of the lava plateau and into the eastern slope of the Cascade range. The plateau structure is here complicated by a series of low anticlinal uplifts with east-west axes, formed after the peneplanation of the region. The Yakima has cut young gorges through the uplifts and aggraded the intervening depressions. Some of the monoclinal margins of the uplifts have suffered from recent landslides on their flanks; a good example is seen south of the railway shortly before reaching Topinish station. North Yakima lies in one of the aggraded depressions, in the center of an important district of irrigated fruit farms, which we visit in the morning.

In the afternoon we continue to ascend the Yakima, crossing several aggraded plains which occupy the depressions, and passing through several gorges eroded in the uplifts; we follow one of the finest of the latter with a pronouncedly meandering course just before we reach the largest of the former, in which Ellensburg is the chief town. The highlands to the north and south of this basin bear the easternmost extension of forests; the lower ground is still treeless, except for orchards of fruit trees and for lines of poplars which serve as windbreaks. Rainfall increases with altitude, from 6 inches near the Columbia river, to 80 or 100 inches near the summit of the Cascades. The forest descends into the valley before the valley head is reached; thereafter the whole region except the higher summits is tree-covered, particularly on the western slope, where the forest growth is very dense. The Yakima heads in three glacial lakes north of our route; the divide is crossed in a tunnel at an altitude of 2850

[1] Based on notes by Professor E. J. Saunders, of the University of Washington.

feet. The western valleys are much aggraded with glacial drift; we follow them down to the open country near Puget sound, and reach its shores at Seattle in the evening.

Our twenty-third day is spent in this vigorous young city, which is connected with the East by three competing railway

FIG. 23. Valley of Yakima River, Washington.

lines, and which has in recent years grown to be the chief port of the Northwest for traffic with Alaska. The local topography being unfavorable to civic growth, an enormous work of grading has recently been undertaken. The State University is within the city limits on the north.

Twenty-fourth Day, Saturday, September 14

SEATTLE TO TACOMA, WASH., AND SOUTHWARD

We go by boat up the sound (southward) from Seattle to Tacoma; the railway between these two cities follows an aggraded trough a little farther east. The shore line is but little changed by wave action from its initial form. Point Pully, about midway on the eastern shore, is a good example of the cuspate forelands which have been frequently built out by eddying tidal currents; deltas occupy the heads of sea arms into which good-sized streams flow. Mt. Rainier rises in the southeast; the Olympic mountains in the west. We spend the afternoon in Tacoma, and go on southward in the evening, passing Portland about midnight and turning eastward up the Columbia river.

Twenty-fifth Day, Sunday, September 15

THE DALLES TO PORTLAND, ORE., AND SOUTHWARD

The early morning finds us at the Dalles in the Cascade range, where the Columbia has cut a gorge through heavy beds of columnar lava. We follow the river downstream in the forenoon, and spend the afternoon in Portland. In the evening, we continue our journey from Portland southward up the Willamette valley; we pass through the Umpqua valley in the night, and enter the Rogue river valley early the next morning.

Twenty-sixth, seventh, and eighth Days, Monday to Wednesday, September 16 to 18

FROM MEDFORD, PAST CRATER LAKE, TO KLAMATH FALLS[1]

The morning of September 16 opens at Medford, where we see abundant fruit farms, and whence we go in automobiles

[1] Based on notes by J. S. Diller, U. S. Geological Survey.

up the valley of Rogue river to the northeast. The Klamath mountains on the west consist of ancient crystalline rocks, from which a great series of younger strata dip under the heavy lava flows which here form the Cascade range on the east. As we ascend into the latter, newer lava streams and tuff deposits are seen filling valleys cut in the earlier lavas. The upper valley of Rogue river has been invaded by a flow in which the river is now working.

The slightly serrated volcanic rim which incloses Crater lake finally rises ahead of us; the volcanic plug of Union peak rises on the southeast; we ascend to the southwestern side of the rim and there spend two nights and the day between them. The lake with a district around it was made a national park in 1902. The altitude of the volcanic rim is from 7000 to 8000 feet; its diameter, five miles; the level of the lake is 6177 feet; its depth, nearly 2000 feet. The ancient volcano, named Mt. Mazama, probably rose to 14,000 feet; its flanks were deeply ravined; the huge cavity of to-day appears to have been formed by engulfment rather than by explosion, because no great quantity of the products of explosion are found on the lower slopes; the engulfment took place after the dissection of the volcano, for the cliffs of the cavity now truncate well-formed radial valleys, the heads of which must once have been much higher than the present rim; the engulfment took place after glacial action had enlarged some of the valleys, for glaciated rocks are found in the present valley heads, as if glaciers had extended down into them from some higher source, now vanished. Wizard island is a young volcanic cone formed in the lake after engulfment.

On the morning of September 18 we take automobiles to descend southward to the town of Klamath Falls, at the eastern base of the Cascade range. We follow the road of our ascent

for a few miles and then turn southeastward down the valley of Anna creek, which has cut a sharp gorge beneath an earlier valley floor. The volcanic plug of Union peak is now seen to the west; a fault scarp and large springs are passed on the way down.

Several extensive water bodies, the Klamath lakes, are held at the eastern base of the mountains by lava sills. The town of Klamath Falls lies between the upper and lower lakes, on the east side of the river that connects them. Great irrigation works are in progress in this district. Our train meets us here, and in the afternoon we run southwestward down a branch railroad following Klamath river through the Cascade range to the main line at Weed in northern California; then going on southward we pass the western slope of Mt. Shasta in the late afternoon. An aggraded basin occupies a depression north of this great volcano; it is drained to the Klamath river, which escapes through the Coast range on the west to the Pacific. The terminal moraine of the Whitney glacier may be seen high in the northern slope of Shasta; several subordinate volcanic cones and knobs rise hereabouts. The railway line crosses a col at the west base of the huge volcanic cone, and we thus pass from Klamath river drainage to the head of the Sacramento river. South of Sisson, the line crosses a lava field and enters the canyon of the Sacramento, which it then follows; remnants of lava flows are seen clinging to the canyon walls for many miles.

Twenty-ninth Day, Thursday, September 19

REDDING TO SAN FRANCISCO

We enter the northern end of the valley plain of California at Redding in the night and follow it southward through the morning. The Marysville buttes, a group of dissected vol-

canic hills rising in the plain, are passed on the way. The Sacramento and its tributaries wander over the plain, which they are aggrading, all the more actively since the auriferous gravel beds along the western flanks of the Sierra Nevada have been extensively washed by the hydraulic method of gold working; the addition of detritus to the lower streams has increased their load so greatly as to cause them to spread sand and gravel far and wide, thus devastating parts of the plain and giving rise to litigation between the agricultural and the mining interests. Detailed maps have been made of this district, to serve as the basis of official investigation of means by which the devastation of the plain can be diminished, and its reclamation effected.

We follow the plain southward to the great marshes of Suisun bay, the innermost expansion of the embayment formed by the depression and drowning of the "Golden Gate." We then approach the eastern base of the Coast ranges, where they constrict the embayment into a narrow passage, known as Karquines strait, which we follow westward, and thus reach an intermediate expansion of the drowned district, known as San Pablo bay on the north, and San Francisco bay on the south. We turn south from Karquines strait, cross a lowland that connects the San Pablo peninsula with the ridges in the east, pass Berkeley, the seat of the State University, and thus reach Oakland, where we ferry across the bay to San Francisco.

Thirtieth and Thirty-first Days, Friday and Saturday, September 20 and 21

SAN FRANCISCO AND LOCAL EXCURSIONS

We are invited to an all-day excursion on September 20 to Mt. Tamalpais, which is reached by crossing the bay to the north and ascending by an inclined railroad to the summit. A grand

view is spread before us, embracing the ridges of the Coast range, the irregular embayment of the ocean, and the ocean itself.

September 21 will be given to several local excursions, as selected by the members of the party. In the afternoon we visit the University of California in Berkeley, and take train in the evening, to begin our eastward journey.

Thirty-second Day, Sunday, September 22[1]

ACROSS THE SIERRA NEVADA TO THE BASIN RANGE PROVINCE

We have ascended the lower western slope of the Sierra Nevada during the night by a winding route on the slanting highland between the young valleys of Bear river on the north and of the North fork of American river on the south. The morning opens on the highlands, which are surmounted by monadnocks and dissected by deep canyons. We may have an early view from Cape Horn, a spur of the highland which projects southward over the canyon of the North fork of American river. On reaching the head of Bear river, we cross the highland to the south side of the canyon of the South fork of Yuba river, which we follow eastward. Monument hill is a strong monadnock on the south; Signal peak is another to the northeast; many glacial lakelets occur on the highlands to the north.

Towards the head of the South fork of Yuba river, its valley becomes open and shallow, as if it were here little changed from the form gained in the earlier cycle, before the uplift and tilting of the Sierra mass. Monadnocks rise around us; signs of glaciation are abundant; the forests have been ruthlessly cut away. We tunnel through the crest of the range under Donner pass (7000 ft.), then loop around the eastern spurs, descending rapidly, passing Donner lake, and thus reach Truckee river, the out-

[1] Including notes by Henry Gannett, U. S. Geological Survey.

let of Lake Tahoe, a beautiful sheet of water which occupies a depression between fault blocks some ten miles to the south. We continue to descend through the winding canyon of Truckee river and thus enter the Basin range province. The first intermont basin is known as Truckee meadows, in which Reno is a considerable city for an arid region; Carson city, the capital of the state of Nevada, and Virginia city, formerly more famous than now for its gold and silver mines on the Comstock lode, lie to the south of our line. Prize fights are permitted and divorce is facilitated in this desert state, as if to add to its attractions.

East of the Reno basin, the Truckee enters a canyon through unnamed mountains, and thus reaches a larger basin in which Wadsworth is the chief town; here is the beginning of the Lake Lahontan area in which we run for a long distance. The river turns northward to Pyramid lake, which occupies a depression between two meridional ranges. Our route passes around the southern end of the Natchez range; then we run northeastward across barren alkali flats, the dust from which frequently adds much discomfort to travel; dust whirls and mirages are often noted; thus we approach Humboldt river, which comes from the northeast and turns southward to reach Carson lake on an extensive intermont plain. The Humboldt river is followed between the Trinity mountains on the northwest and the West Humboldt range on the southeast; a fault has been traced along the nearer base of the latter, and the range is therefore believed to be a dissected fault block. We stop in the depression between these two ranges, to examine a series of shore ridges formed by the currents and waves of Lake Lahontan; they are so arranged as to indicate many pauses during a long period of rising waters, followed by a rapid disappearance of the lake. We go on up the Humboldt river, still following the bed of the ancient lake, to Winnenmucca and beyond in the evening.

Thirty-third Day, Monday, September 23

ACROSS GREAT SALT LAKE TO OGDEN AND SALT LAKE CITY

We enter the area of Lake Bonneville by a gap in the Gosiute range, continue across the lake-bottom plain, and cross the northern part of Great Salt lake, a very shallow sheet of water, by a long embankment, which was recently constructed with much difficulty, to avoid the long detour of the original route north of the lake. We pass Terrace, Lakeside, and Promontory ranges, which were all islands in Lake Bonneville, the shore lines of which are traced all around their flanks at various levels. We thus reach Ogden, near the base of the Wasatch range, which limits the Basin range province in the east.

The most significant features to be observed while we are in the Basin range province are: The generally well-dissected and subdued forms, in which the structure is commonly concealed under a graded cloak of creeping waste. The occasional outcrop of rock ledges, in which the structure of the mass is all the more clearly shown by reason of the scantiness of vegetation. The prevailing indifference of the base line of a range to its lines of structure, thus indicating, if the slope is steep and the base line simple, that the range there exhibits a dissected fault scarp; or if the slope is gentle, that it there exhibits the inclined back of a tilted block, which had already been reduced to moderate or small relief before block faulting took place. The occasional occurrence of triangular facets, sometimes well defined, more commonly rounded and blurred by weathering, by which the mountain spurs are truncated along the simple base line of a dissected fault scarp; on the other hand, the occasionally vague ending of low, sprawling spurs and hills, which merge irregularly and indefinitely with the aggraded intermont plains, thus giving the impression that they are the last remnants of a worn-

out mountain system, not refreshed by renewed elevation. The long slopes or fans of waste, heading in each ravine of a mountain side and spreading forward with gradually decreasing slope far into the intermont depressions; the coarse texture of the waste near the apex of the fans, where exceptional floods from the mountains have swept out great bowlders; and the flat floor of the central depressions, sometimes subdivided into separate compartments by the unequal advance of the larger fans. The occasional occurrence of recent fault scarps which traverse the fans near their apex, parallel to the mountain base, thus indicating renewed movement on the fault by which the mountain block was uplifted. The shore lines of different types traced at various levels along the mountain slopes. The moderate size of the deltas at the highest shore-line level, because the streams of that stage were devoted to filling the long bays formed by drowning the valleys in the mountains; the much larger size of the deltas of lower levels, because much of the unconsolidated filling of the drowned valleys was then rapidly washed out into the main body of the lake. The occurrence of Bonneville shore lines on the slopes of previously formed fans of large size, thus indicating that a long period of arid climate had preceded a relatively short-lived period of humid climate. The vastly greater mass of the mountains than that of the fans at the ravine mouths, thus indicating that the period occupied in building the fans was a very small fraction of an entire cycle of mountain erosion; hence the vanishingly short duration of the humid climate of Lake Bonneville, in comparison either with the cycle of mountain erosion that preceded, or with the cycle that is now following the block faulting of the region. The redemption of all the irrigable parts of the desert by the settlement of the Mormons, begun seventy years ago. The recent shrinking of Great Salt lake, as if on account of the with-

drawal of its few inflowing streams for irrigation. The great density of the lake waters, as indicated by the ease of floating in them; and their extreme salinity, as indicated by the painful smarting caused if the water enters one's eyes or ears — an experiment that is not worth trying.

It was at Ogden that the two sections of the first Pacific railroad — the Union Pacific from the east and the Central Pacific from the west — were united in 1866. The line of the Union Pacific comes through the Wasatch range by the deep canyon of Weber river. We turn southward from Ogden to Salt Lake city, and on the way have a fine exhibition of the dissected fault scarp of the Wasatch front, with its faceted spur ends and high-level shore lines. Some of the alluvial fans near our route are crossed by recent low fault scarps.

Thirty-fourth and fifth Days, Tuesday and Wednesday, September 24 and 25

EXCURSIONS NEAR SALT LAKE CITY AND PROVO, UTAH

Details of these excursions not being completed at the time of printing this Guide, they will be announced later, during the journey. They will probably include a visit to the dissected fault scarp of the Wasatch range, possibly at a point where glacial moraines advance upon the piedmont plain and suffer recent faulting along the mountain base line; a visit to some mines in the Oquirrh range, a good example of one of the Basin ranges, with prevailingly subdued forms and waste-covered slopes, and with a fine series of Bonneville shore lines around its northern end; and a visit to the recent fault scarps at the base of the Wasatch range east of Provo, on the afternoon of our departure for Colorado. Later in that afternoon, we follow up the valley of Spanish fork, where it flows westward through the

Wasatch range south of Provo, and thus enter the northern part of the Plateau province, in which we continue all night.

Thirty-sixth Day, Thursday, September 26

GRAND JUNCTION TO GLENWOOD SPRINGS, COLO.

In the early morning before daybreak, we cross Green river, a short distance south of its canyon through a high plateau, of which the elaborately dissected south-facing escarpment is known as the Book cliffs, one of the strongest examples of its kind in the region. To the southwest is the greatly denuded region of the San Rafael swell, in which a daylight trip barely shows the summits of the laccolithic Henry mountains, made famous by Gilbert's early studies. As we progress eastward, a gradual transition is made to more disturbed structures; and thus we leave the Plateau province and enter the Rocky mountain system. Here we reach the valley of Grand river, which unites with the Green to form the Colorado. At the junction of Gunnison river, which comes from the southeast, with the upper Grand, which comes from the northeast, lies Grand Junction with its extensive irrigated orchards; here we spend the morning.

In the afternoon we follow up the valley of Grand river, which is alternately narrow in the resistant rocks, especially in the fundamental crystallines and the basal sandstones of their covering strata, or maturely opened in younger structures of less resistance. After reaching Glenwood Springs, we continue up the canyon of the Grand river, there eroded through the covering sandstones into the underlying granites; here we pass the works of the Central Colorado Power Company, first seeing the power house, to which the water is led through pressure pipes from a tunnel in the canyon wall, and then, two and a half

miles farther up the canyon, the dam where water is diverted from the river to the tunnel. The transmission lines of this company, constructed at great expense, extend to Denver, 153 miles distant; we shall see them crossing certain mountain passes at altitudes of 10,000 and 11,000 feet.

On approaching the town of Gypsum, the resistant rocks are left behind and the valley opens to mature form; here a curious feature is seen in an isolated lava flow of recent date far in the continental interior. Its vent is on the northern valley side; the flow spreads across the valley floor and pushes the river against the southern side. This lava flow is one of the not frequent examples of a first eruption in a non-volcanic district; it thus stands in strong contrast with the recent flows of central France, which are the closing episodes in a volcanic period of long duration. We return to Glenwood Springs, where we pass the evening. Towards midnight our train takes us up the valley of Eagle river toward the continental divide in the Sawatch range.

Thirty-seventh Day, Friday, September 27

HAGERMAN PASS TO DENVER, COLO.

The morning opens on the northern side of the valley, or glacial trough, of Fryingpan river, a branch of Eagle river, which here drains the western spurs of the Sawatch range, a part of the continental divide. Fine bank moraines are seen near the track. A hanging side valley joins the main valley from the south, and a delicate terminal moraine is seen crossing the glaciated ledges just beneath the hanging valley mouth. We turn northeast up another hanging side valley of pronouncedly trough-like form, and follow it past the head of its deepened trough, where the huge rock cliffs have gained the name of Hellgate. The top of a fine mountain dome, of typically subdued

form although about 13,000 feet in height, is seen ahead; it forms part of the continental divide. We continue eastward up the shallower trough floor to the western entrance of a tunnel under Hagerman pass in the crest of the Sawatch range. Here we walk over the crest, leaving the waters of the Colorado system behind us, as we ascend the graded and grassy western slope to the pass, and then turning for a short ascent to the summit of a half-dome, surmounted by a group of ungraded granite crags, whence we look down on the headwaters of the Arkansas-Mississippi system.

The most striking feature of the view results from the unsymmetrical distribution of glacial erosion. Owing to the west winds, the present action of which is seen in the forms assumed by stunted trees near the pass, the glaciers formed on the western slope were small; those in the eastern valleys were much larger, and there the valley heads were enlarged into cirques. Sometimes a cirque has consumed only a small part of a subdued domelike mountain top; other cirques have consumed more than half of a dome, and as a result the mountain crest has a very unsymmetrical cross profile.

We descend into the rugged eastern cirques by an easy path, take the train at the east end of the tunnel, and then follow the south side of a well-developed trough system to the terminal moraine, which, with several others of similar origin, advances into the open intermont basin of the upper Arkansas river. The famous silver-mining town of Leadville lies on the slope to the east. As we turn southward along the flat basin floor, fine views are gained of the huge undissected body of Mt. Massive on the west. Large moraines stretch eastward into the basin from a valley trough on the south side of Mt. Elbert; the Twin lakes lie in the morainic basin, not seen from the train; the level of the lakes has been raised to increase their storage capacity;

the water is drawn off to the river, to be diverted in irrigating canals many miles downstream, east of the mountains; but the farmers who have earlier rights to the natural flow of the Arkansas insist that the later comers small not draw off as much water to their canals as they turn into the river from the Twin lakes reservoir, for part of that supply is lost by evaporation on the way.

Still larger moraines south of those of Twin lakes advance so far that they push the Arkansas close against the eastern side of its basin, where it undercuts the rocky slopes in a narrow gorge; at the upper end of the gorge lies the village of Granite. After passing this gorge, the basin opens again, and we begin the oblique ascent of the eastern slope, among abundant granite bowlders of local weathering. We here enjoy a fine view of the southern half of the Arkansas basin; the aggraded floor slopes eastward from the higher mountains of the Sawatch range on the west; the town of Buena Vista lies in the middle of the basin; the river, heavily freighted with coarse bowlders, is pushed close along the base of the eastern slope. Three summits in the Sawatch range are known as the College peaks; to the northwest is Mt. Harvard, to the west, Mt. Yale, both over 14,000 feet: these two peaks were first ascended and measured in 1869 by a party led by J. D. Whitney, a graduate of Yale and then professor at Harvard; the director of the present Excursion was a member of the party, and was the first to reach these two summits. Mt. Princeton, next to the south, was named a few years later by Hayden's survey party, among whom was Henry Gannett, also a member of Whitney's party of 1869. Moraines extend out upon the basin floor from the valleys between the peaks.

We turn eastward into a side valley, and soon cross over an open pass by which we enter South park, one of the highest of those broad, intermont plains which characterize this part of the Rocky mountains. It affords excellent pasture in summer, but

is too cold for cattle in winter. Pikes peak rises to the east, a great monadnock standing about 4000 feet above the Rocky mountain highland in this district. Cripple creek, a famous gold-mining camp, now past its prime, lies on the highland to the south of Pikes peak. We cross the park and leave its eastern side by a canyon which the South Platte river has cut in the granitic highland; but we soon turn out of the canyon to cross a gravel-covered district at an altitude of about 10,000 feet, northwest of Pikes peak; and then descend rapidly to the Great plains at the base of the mountains.

At the point where we descend, the usual nearly rectilinear, north-south trend of the mountain front is interrupted by a westward embayment, at the apex of which lies the town of Manitou. The greater part of the embayment is occupied by inclined sandstones which dip southeastward from the mountains; they frequently form monoclinal ridges, of which the most striking members are included in the "Garden of the Gods," a few miles to the north. The southwestern side of the embayment is a fine example of a fault-line escarpment; here the monoclinal strata are cut off, one after the other, along an oblique line. Many springs rise along the fault line. The mountain front is limited by the same fault line instead of by a monoclinal flexure for several miles to the southeast; and the mountain front in that district is therefore a dissected fault-line scarp, instead of a stripped surface of ancient erosion.

We run out of the embayment to Colorado Springs, noted as a residential city on the border of the plains; a low mound on the plains a little farther east is known as Mt. Washington, because its altitude is the same as that of the dominating summit of the White mountains in New England. We turn north and approach the mountain front where it advances at the northern border of the Manitou embayment, and continue ascending the

apparently subsequent valley of Fountain creek, a tributary of the Arkansas, inclosed on the east by a retreating cuesta-like escarpment of plains strata. The valley narrows to its head, where the railroad, running close to the mountain base, passes over to a similar valley of northward discharge, which leads to the valley of the South Platte, in which lies the city of

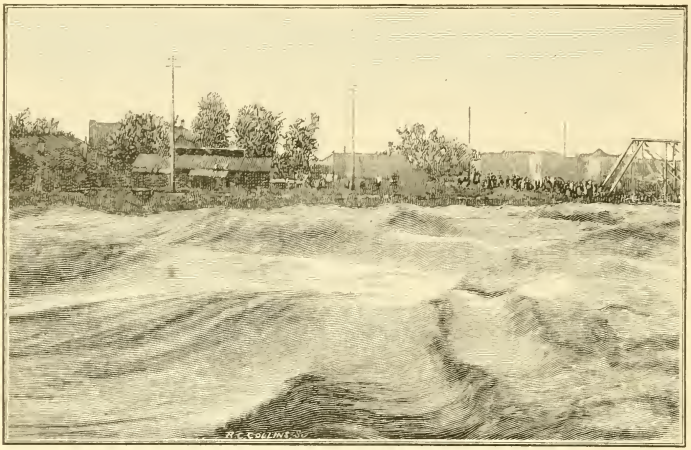

FIG. 24. Flood in Cherry Creek, Denver, Colorado.

Denver, the largest city of the plains; we arrive there late in the evening. The streams of this district are subject to sudden floods, and the detention of trains by "washouts" is not uncommon.

Thirty-eighth Day, Saturday, September 29

FROM DENVER TO THE CONTINENTAL DIVIDE AND RETURN

A local train carries us northward from Denver; we soon cross the valley of Clear creek, broadly excavated below the general level of the plains, to which ascent is then gradually made northwestward. As we rise it may be perceived that the present

valley floor of Clear creek, which flows eastward from the mountains, is bordered below the plains level by the remnants of an earlier valley floor, which now form lateral terraces, more or less dissected by side streams. Irrigating canals or "ditches," running along the valley sides, mark the boundary between the abundant vegetation of cultivated field and orchards and the scanty herbage of the treeless plains.

The simple margin of the Front range, with its highlands and its monadnocks, is now well seen to the west. Two lava-capped table mountains stand north and south of Clear creek near its exit from its gorge in the highland. To the south, Green mountain is an unconsumed remnant of the plains strata, not wholly removed in the general peneplanation of these weaker rocks. On approaching the mountains, the plains strata, exhibited in the cuts of the winding railroad as it ascends to the full height of the plains, are seen to be steeply inclined for a mile or more from the mountain base; the inclined strata are evenly truncated and covered with "wash" from the mountains. This makes it clear that the broad surface of the plains between the shallow valleys is not a surface of original deposition, but a surface of penultimate planation. It may be noted that the erosion of the existing valleys below the plains does not require the uplift of the region: in view of the great distance from the sea it suffices to assume a slight change in the relation of stream activity to the load of waste which the streams have to carry, to cause them either to degrade or to aggrade their previously graded courses; and this change can be brought about by variation of climate as well as by a regional uplift or depression.

Some of the more resistant plains strata near the base of the series form monoclinal ridges or foothills, frequently notched by consequent stream channels, and separated from the mountain base by a longitudinal depression, consisting of many confluent

subsequent valleys. The simple mountain front is a geographical fossil; it is part of the ancient erosion surface on which the plains strata were deposited; the ancient surface was long preserved by burial; the compound mass was then flexed, peneplained, uplifted, and eroded; thus the covering strata are now worn off from their foundation; the ancient surface is thus revealed in the simple spurless mountain front of to-day; it is somewhat overlapped by unremoved strata near the base, somewhat the worse for wear near the top, and repeatedly cut down by the valleys of outflowing streams. Occasionally some of the most resistant basal red sandstones cling to the sloping mountain front and rise to the top; we see good examples of these as we reach the mountain base; they become stronger a little farther north, and rise in peaks even above the level of the crystalline highland; these are known, when seen from the plains, as the "Flatirons," from their triangular form and smooth exterior slope. As we skirt the mountain border, a fine prospect is afforded over the treeless plains, which extend eastward more than 500 miles.

We turn from the mountain front into the submature gorge of South Boulder creek, deep cut in the granite rocks of the Front range highland, and follow the southern wall at mid-height, cutting through many spurs in short tunnels. The village of Eldorado Springs is seen below us as we enter the gorge; the contact of the resistant basal members of the plains strata and their crystalline foundation surface, both steeply inclined, is well shown on the northern side of the gorge. The fall of the creek being more rapid than the grade of the railroad, the depth of creek below the track decreases, and after a few miles we find ourselves running close to the bottom of the gorge. We then rather abruptly enter the broad basin of Boulder park, a glaciated trough, with truncated spurs and hanging lateral

valleys. The small volume of morainal material at the lower end of the trough, where we enter it, is interesting in view of the great amount of glacial erosion indicated by the breadth and depth of the trough.

After following the trough floor for several miles, past the small summer resort of Tolland, we turn back by a semicircular curve and ascend the northern trough side by a double loop; then pass northward out of this trough into a smaller one, which we follow up to a group of well-defined cirques, excavated in the eastern slope of some low monadnock domes which here surmount the highland and determine the range crest. We loop around the head walls of the cirques, and then again pass northward to the southern wall of the great glacial trough of Middle Boulder creek, which like South Boulder creek is a tributary of the Platte-Missouri-Mississippi system. This trough heads in a strong rock step, above which is a fine group of cirques. We pass around the mountain crest to the southwest, and there find that we have crossed the continental divide, as the slope now descends westward to Middle park, a large intermont depression, the waters of which flow by Grand river to the Colorado and then to the Pacific ocean. Here lies the switching station of Corona in a long snowshed, where we leave the train for an ascent by an easy stroll up the western slope, to the monadnock domes which form the crest of the range.

Glacial action is not apparent here; but on reaching the crest we find that the convex domes are more than half destroyed by the excavation of strongly concave cirques on the eastern slope. The view here deserves careful study; it is by no means Alpine, but it is thoroughly characteristic of the Rocky mountains. To the east the gently sloping highlands of the Front range are surmounted by occasional monadnocks and dissected by glacial troughs and normal stream valleys; far in the distance stretch

the Great plains, with their oceanlike horizon. To the south rises James peak, singular in preserving a small part of its preglacial dome summit between great cirques that encroach on all sides. To the north rise the Arapahoe peaks, sharpened by a more pronounced enlargement of several cirques; in one of them lies a small glacier. Next to the east is Bald mountain, of less height and well-rounded form, apparently unaffected by glacial action; it is a good example of *Mittelgebirgsform* at the height of *Hochgebirge*. To the west, the descent is rapid to the broad, high-level basin of Middle park.

The mature glacial troughs and normal valleys of the Boulder creeks are evidently of later origin than the gently undulating highland in which they are incised. The highland surface shows the features of old age. It must have had less altitude and less eastward inclination from the range crest to the range front, while it was worn down to its gently undulating relief, which here and there deserved to be called a peneplain; but it could not have been a lowland near sea level, because its rivers even in their old age must have had some slope to the sea, and in view of their great length of nearly 1500 miles, their headwaters may well have had an altitude of 5000 or 6000 feet. The peneplain now stands at altitudes of from 9000 to 11,000 feet; hence it must have suffered strong regional uplift, or up-arching, since peneplanation. Before this regional uplift, the surface of the peneplain on the crystalline rocks of the mountains area must have been continued by a smoother peneplain on the weak rocks of the plains area; it is only since the uplift of mountains and plains together that the plains have been worn down lower than the mountainous highland. The height of the mountains over the plains is therefore not so much the result of the local uplift of the mountains, as of the widespread erosion of the plains after a broad uplift of the whole region.

The peneplanation of the region must have occurred after the formation of the flexure by which the mountain border is determined, for the even surface of the highlands makes a well-defined angle of 30° or 40° with the dip of the inclined basal members of the plains strata. Hence the surface of the highlands is of much later date than the inclined ancient planation surface — the geographical fossil — revealed by stripping the plains strata from the mountain front; a long period of deposition followed by a strong monoclinal bending must have elapsed between the two great periods of erosion in which the resistant crystalline rocks of the mountain mass were worn down to low relief. The Front range is therefore a morvan; its earlier peneplain was remarkably smooth; the covering strata measured thousands of feet in thickness; the tilting of the compound mass was accomplished by a strong monoclinal flexure sometimes broken by faulting; the later peneplain retained numerous monadnocks in the area of crystalline rocks; the regional elevation was accompanied by arching, which defined the crest of the range and gave the eastern part of the highland its manifest eastward inclination; and the cycle of erosion thus introduced has already attained an old stage on the weak strata of the plains and early maturity in the hard rocks of the mountains, with recent episodes of glaciation in the higher valleys and of renewed valley erosion in the plains.

The afternoon return to Denver reverses the line of the morning ascent.

Thirty-ninth Day, Sunday, September 29

PUEBLO, COLO., TO RATON, N.M.[1]

The night run southward from Denver has brought us past Colorado Springs to Pueblo on the Arkansas river, some 20

[1] Based from thirty-ninth to forty-fifth days in part on notes by W. T. Lee, U. S. Geological Survey.

miles east of the mountains. There we turn west up the river, and pass into its canyon in the Front range, where we find ourselves at daybreak. It is here that the Arkansas escapes from the southern end of the intermont basin, which we saw on our thirty-seventh day. We return through the deepest and narrowest part of the canyon, known as the Royal gorge, cut in crystalline rocks, with unusually steep walls.

Below the gorge, we pass Canyon city and Florence, which with their irrigated fields lie near the mountain base in a denuded embayment similar to the one we saw farther north at Manitou; monoclinal foot-hill ridges may be seen following the border of the embayment to the north. We return to Pueblo and then run about 80 miles farther down the irrigated Arkansas valley, on the way passing Rockyford, famous for its melons. At La Junta we turn southwestward and travel across the peneplain of the Great plains, with unconsumed mesas on either side, to the valley of the Purgatoire river, — "Picketwire" in cowboy English, — a branch of the Arkansas, in the foothills of the mountains at Trinidad. There the most striking object is Raton mesa, a lava-capped mass, culminating in Fishers peak, the altitude of which testifies to the depth of erosion — more than 3000 feet — by which the surrounding peneplain was produced. To the west rise the Spanish peaks (not to be confused with a similarly named section of the Wasatch range in Utah), a deeply dissected volcanic mass, around the base of which many dikes take the form of natural walls. Coal is mined in the dissected plateau northwest of Trinidad; the coal beds occur at horizons above a conspicuous gray cliff.

We ascend toward the south and tunnel through Raton pass, west of the mesa of the same name; here we cross the Colorado-New Mexico boundary; descent is then made to Raton, where our train turns eastward on another line to see something more

of the volcanic district, which extends nearly 100 miles from Raton mesa to the Mesa de Maya. The lava sheets are of various ages; the oldest cover the highest mesas to the north, and rest upon a high-level peneplain formed on the plains strata; flows of much younger date are crossed by our road or cap low mesas to the south. A very recent and well-formed volcanic cone, Mt. Capulin, rises not far from the track. We return to Raton in the evening, and continue our journey southward through the night.

Fortieth Day, Monday, September 30

PECOS RIVER TO ALBUQUERQUE AND BEYOND

Our itinerary here is not definitely settled at the time of preparing this Guide; hence details must be left for the daily bulletins issued on the train. During the night we have followed near the eastern base of the Rocky mountains, and in the early morning turn westward around their southern end. Here the Pecos river, a tributary of the Rio Grande, flows south of our crossing as a consequent stream through the subsequent monoclinal sandstone ridges that encircle the end of the range; but upstream from our crossing the river follows a subsequent valley between the mountain slope and the escarpment of Glorieta mesa, really a cuesta, on the southwest; and the railroad runs between the two. The mountains in the north have subdued forms. Santa Fe, the site of an ancient Indian town, occupied by the Spaniards three centuries ago, lies in the western foothills of the mountains, a little north of our route. Spanish names abound in all this region. We round the northernmost point of the mesa, and cross a divide to a tributary of the Rio Grande, which we follow southwest to the main river. Near Cerrillos station, we pass between two laccolithic mountains,

Los Cerrillos on the north, noted for their turquoise, and the Ortiz mountains on the south. A few miles beyond we enter the valley of the Rio Grande, which has come through a canyon in its escape from the great intermont basin of San Luis valley, the southernmost example of its kind in the Rocky mountains system. The valley which we now follow to the south is an aggraded depression formed by the eastward tilting of two fault blocks, of which the eastern one, Sandia mountain, with its dissected fault scarp facing us, rises nearly to 12,000 feet altitude, or 7000 feet above the valley. This district is therefore a part of the Basin range province, which here advances far eastward to meet the Great plains in eastern New Mexico, and cuts off the Rocky mountain system from the southern extension formerly attributed to it. To the west, across the river, the Albuquerque volcanoes surmount an upland of sand and gravel. The Indian pueblo of Santo Domingo is near the railroad on the west.

We continue southward along the Rio Grande past Albuquerque and the Indian pueblo of Isleta, and then turn westward; beyond Rio Puerco and up its northwest branch, Rio San Jose, we come to the same series of strata that is exposed east of Rio Grande, the members first seen here, dipping northeast, corresponding to those forming the back (eastern) slope of Sandia mountain. Some recent lava flows are passed; the Indian pueblo of Laguna lies near the railroad; the more famous ancient pueblo of Acoma lies about 15 miles to the southwest of our route. To the northwest Mt. Taylor, a dissected volcano, rises over a lava-capped plateau, but the views of it from the railway are inadequate and fail to give a proper conception of its great size. During the night of our westward journey, but probably by daylight on our return (forty-sixth day), we pass north of the denuded and subdued mass of the Zuñi mountains,

the crystalline rocks of which belong to the foundation of the heavy series of strata which we have seen dipping north and northeast after crossing the Rio Grande; it is this series of strata that is uplifted in Sandia mountain, east of the Rio Grande, but the uplift there was not great enough to expose the fundamental rocks. We follow a broad subsequent valley excavated along a belt of weak strata which dip gently from the crystalline rocks northward beneath a heavy series of red sandstones; these rise in a strong escarpment, peculiar in having very little talus because the sandstone crumbles to sand instead of falling in large blocks. The north south continental divide crosses this east-west subsequent valley; the eastern drainage runs to the Rio Grande and the Gulf of Mexico; the western drainage to a second Rio Puerco, and then by the Little Colorado to the Colorado river of the West and the Pacific. Beyond the divide, the subsequent valley and the inclosing ridge with its red sandstone escarpment turn southward around the western side of the Zuñi mountain uplift; we continue westward through an open consequent breach in the ridge, in which the dip of the sandstones rapidly increases; we then cross another north-south subsequent valley, and pass through a breach in a ridge of vertical gray sandstones; and after crossing still another subsequent valley, come to an upland of horizontal strata, in which coal is mined; here is the town of Gallup. We have thus crossed the great Nutria monocline, one of the grandest structures of its kind in the West; Dutton has described it admirably, and has emphasized the enormous erosion that the eastern uplifted area has suffered. The line of the monocline is marked by the ridge of vertical sandstones, with older strata on the east and younger strata on the west, all now reduced to about the same relief. The vast amount of denudation thus indicated may be referred to the earlier cycle of erosion of the Plateau province; in this

district the later cycle, now current, has not yet succeeded in producing deep dissection. The strong relief possessed by Sandia mountain suggests that its uplift is of much later date than that of the Nutria monocline.

Forty-first Day, Tuesday, October 1

WINSLOW, ARIZ., TO THE GRAND CANYON OF THE COLORADO

The morning finds us on the undissected plateau country drained northwestward by the Little Colorado. A low escarpment to the north is peculiar in possessing an extremely coarse talus of huge blocks, which are broken from the capping sandstone by the sapping of the underlying clays, thus contrasting strongly with the much higher red sandstone escarpment seen north of the Zuñi mountains, where the talus was scanty. The sandstone escarpment here seen contains many fragments of silicified wood, and at an outlier south of the railroad, reached from Adamana station, abundant tree trunks have given the locality the name of the Petrified Forest; we may be able to visit it, either going or coming. The widespread removal of the sandstones and clays of this escarpment, and of many other overlying formations which have now retreated far to the north, indicates that the area of resistant limestones to the south of us is a stripped plateau, and that the broad valley of the Little Colorado which we are following is a subsequent valley still exhibiting the features of the old stage of the earlier cycle, although broad uplift has introduced it into the new cycle, now current. Farther downstream, to the northwest, the Little Colorado has followed the example of the main Colorado in taking advantage of the new uplift to intrench itself in a canyon, deep below the denuded surface of the earlier cycle; but here that work is still potential, not yet actual.

We cross the Little Colorado at Winslow; it follows the old subsequent valley lowland to the northwest; we obliquely ascend the long slope of the stripped limestone plateau to the west. Occasional remnants of overlying sandstones appear in curiously isolated forms; a small consequent stream has cut a narrow trench in the limestones, known as Canyon Diablo. The dissected volcano, Mt. San Francisco, rises ahead of us, with pine forests on its flanks and snow patches on its summit; we pass it and its dependent volcanic forms on the south; at Flagstaff the old stage road ran north to the Colorado canyon. Forested volcanic mountains in advanced, subdued stages of dissection continue to diversify the barren plateau. At Williams, we turn north by a branch line; the volcanic mountains are soon left behind; with the gradual ascent of the surface, tree growth sets in and we enter the Coconino forest. Red butte, a lava-capped outlier of higher strata, elsewhere stripped away for scores of miles, rises over the forest to the east. We gain a brief glimpse of the Grand canyon; its farther wall and the even sky line of the Kaibab plateau are seen miles away to the north across a void space, but the bottom of the canyon is far below our high line of sight. A slight rise of the ground closes the view; we reach the end of the line and walk up the little slope to the canyon rim.

The end of the afternoon is free for short walks east or west to the promontories of the plateau. We spend this and the following night at El Tovar hotel.

Forty-second and third Days, Wednesday and Thursday, October 2 and 3

AT THE GRAND CANYON OF THE COLORADO

The descent into the canyon is planned for October 2; for the next day there is no special plan till the early evening, when we take train for Phœnix.

The features of special interest to be noted during our stay at the canyon are as follows: The compound structure of the plateau mass as revealed in the canyon walls; namely, a foundation of deformed and resistant crystalline sheets, commonly spoken of as the "granite"; a heavy series of strata, resting unconformably on a remarkably smooth floor or planation surface of the crystalline rocks, inclined to the southeast, and truncated in wedgelike form by a second planation surface which transects the crystalline rocks as well; a heavy horizontal series which covers both the older rock series unconformably and builds up the even surface of the plateaus. The three members of the tripartite mass may be conveniently spoken of as the foundation, the wedge series, and the plateau series. The wedge series is here cut off by a fault, which uplifts the foundation crystallines on the east; the fault was evidently of earlier date than the second planation, as it is evenly crossed by the plateau series, for which the second planation prepared the floor. Some twenty miles to the east, the wedge series is seen again and in much greater volume; its inclined strata, mostly sandstones and slates, often of bright red color, there measure about 11,000 feet in thickness; their uppermost members are not seen because the monoclinal flexure, which limits the Kaibab plateau on the east, carries all these older structures below the river level in the Marble platform block.

The plateau series includes a resistant sandstone at the base, a heavy and resistant limestone near the middle, and several resistant sandstones and limestones near the top, all these being separated by weaker strata; thus the series may be spoken of as including several cliff makers and alternate slope makers. The topmost member of the series here visible is by no means the top of the entire stratified series in the Plateau province; the uppermost members rise, from 70 to 100 miles north of the

canyon, in a series of great escarpments to the High plateaus of southern Utah; hence they may be called the high-plateau series. They have been stripped from a vast area of country, and only occasional outliers of their lowest members, as seen in Red butte south of the canyon, now remain as witnesses of their original extension. It is of geological interest to note that the middle and capping members of the plateau series are of Carboniferous date, and that the basal members are of Cambrian date; all the formations, from the Cambrian sandstones at the base of the plateau series, to the Eocene strata at the top of the high-plateau series, follow in conformable sequence, except for a slight unconformity by erosion without deformation in the Permian; the wedge series is pre-Cambrian, being separated from the Cambrian by a completed cycle of ancient erosion; the foundation rocks are of complicated history, but are older than the wedge series by another completed cycle of erosion; thus the perspective of the past opens to us, through the illimitable "corridors of time."

None of the larger faults and flexures of the Plateau province are visible from our point of view at the canyon, though glimpses of the flexure at the eastern side of the Kaibab may perhaps be gained from some of the promontories. A small fault traverses the plateau a short distance west of El Tovar; it is presumably of the same date as the greater ones; it is now significant only in producing a dull and low fault-line scarp, along the base of which a fault-line valley on the plateau surface leads to the head of a side canyon.

The evidence in favor of an earlier cycle of erosion, in which the Plateau province was broadly denuded before being broadly uplifted to its present altitude, is not clearly seen near the canyon, but it has been well substantiated by several observers elsewhere. We can here see its perfect accomplishment in the even sky line

of the Kaibab plateau to the north; but that plateau, when visited, is found to be maturely dissected by shallow ramifying valleys, while the lower Marble platform on the east and the lower Kanab plateau on the west, capped by the same limestones as the Kaibab, are much less dissected; hence it is supposed that the present surface of the Kaibab block rose 1000 feet or so above the lowland surfaces of the adjacent blocks at the close of the first cycle of plateau development.

The canyon is of unsymmetrical cross section; the river is much nearer to the Coconino plateau on the south than to the Kaibab plateau on the north, because of a gentle southward dip of the strata. The form of the canyon walls responds so closely to the structures of the plateau mass that these structures, however long they have been monopolized by geology, must inevitably be mentioned in any detailed geographical account of the canyon; and all the more because of their manifest exposures in the absence of abundant vegetation. The hard crystalline rocks of the foundation hold the bottom of the canyon narrow; hence that part is often called the "inner gorge." The cliffs and slopes of the higher walls follow their controlling structures with accuracy. The cliff face of the heavy middle limestones, themselves of the usual bluish color of such rocks, is stained by the wash from the overlying red shale, and hence the limestone cliffs are called the "red wall." A platform is stripped on the red-wall cliffs as well as on the basal sandstones; but while the sandstone platform at the lower level, underlaid by the resistant foundation, is little dissected, the limestone platform, at the higher level and underlaid by weak shales, is much more dissected; the sandstone platform is cut back by each wet-weather side stream in a narrow and sharp-headed ravine, while between the ravines it advances in broadly rounded promontories; the red-wall cliffs under the limestone platform retreat

in great rounded amphitheaters and advance in sharp cusps. The high-level cliffs of the plateau rim recede in open embayments between blunt promontories. All these forms are the necessary and systematic result of normal erosion on a heavy mass of horizontal strata of varying resistance. Wind erosion is undoubtedly of importance in the canyon, and some observers have attributed the great amphitheaters of the red-wall cliffs to its action; but as a form-producing agency it is subordinate to the action of wash and creep under the persistent down-slope impulse of gravity.

The main canyon is so young that its rapid river has hardly begun the widening of the canyon bottom; indeed, in the hard rocks of the inner gorge, the river occupies the entire breadth of the cut, from wall to wall; yet the canyon is ten or twelve miles wide at the plateau level. Hence, although the canyon is ordinarily spoken of as the work of river erosion, it must be tacitly understood that the larger part of the work has been done by the weathering and washing of the walls; this river, like all rivers, has really carried away much more waste than it has cut. If the term "erosion" is really limited to the destructive work of running streams, there are no such things as "valleys of erosion," and still less "mountains of erosion"; but the common use of these phrases shows that the actual meaning of erosion, in practice, is much larger than its definition in textbooks. Waterfalls on ungraded resistant strata are rare or unknown in the main river, but abundant in the wet-weather streams of the side canyons. All the side canyons, except the very smallest, are cut down to accordant junctions with the main river, even though they are only the work of intermittent streams. The largest one here seen is that of Bright Angel creek, which comes from a great embayment in the Kaibab plateau. Great as is the work already accomplished in the excavation of the canyon, it is only

a small beginning of the task assigned to the river during the current cycle of erosion; the uncut plateaus to the north and south are very young. At the mouth of each side canyon, delta-like heaps of bowlders are swept out by occasional floods; quiet pools occur above the bowlders, but where the river is constricted and steepened by the bowlder heaps, it rushes in violent rapids; the rapids thus formed were the chief difficulty encountered by Powell in his exploration of the canyon by boats forty-five years ago. The heavy charge of silt borne by the rapid river scours and polishes the ledges and bowlders in its channel.

Botanical geographers will find much to interest them in the flora of the canyon. A change of climate is indicated by a change of vegetation as one descends from the pine forest of the plateau to the bottom of the canyon, where the plants resemble those of northern Mexico. The prevailing dryness of the air is indicated by the contrast between the warmth of sunshine and the coolness of shade, although this is less apparent in October than in July. The clearness of the air, taken with the magnitude of the canyon forms, makes it difficult to estimate distances. The strong, ruddy colors of the illuminated walls and the deep purple of the shadows cast by the promontories are striking features of the half hour before sunset; the slow rise of the steel-blue shadow of the earth on the clear eastern sky, beneath the rosy twilight arch, is a characteristic feature of the following half hour. At night the visibility of stars close to the horizon tells us we are in an arid land.

The improvement of our topographical maps is well illustrated by comparing the generalized contours on the smaller-scale sheets of earlier surveys of the plateau region with the accurate and expressive contours on the newer large-scale sheets of the canyon.

Forty-fourth and fifth Days, Friday and Saturday, October 4 and 5

PHŒNIX, ARIZ., TO THE ROOSEVELT DAM AND RETURN

During the night we have gone a short distance west of Williams on the main line of the Santa Fe railway to Ashfork, near the western margin of the Plateau province; there we turned southward, descended the dissected escarpment in which the plateau country terminates, and entered the Basin range province. After running through various aggraded depressions in the complex of mountains, we pass between the Weaver mountains on the east and the Date-creek mountains on the west to a broad basin, in which we descend a long waste slope southward and thus reach the more open desert country of southwestern Arizona, in which the mountains are small and isolated, while the barren aggraded plains are of great extent. We turn eastward and during the early forenoon reach Phœnix in an irrigated district on Salt river, which comes from the mountains and the dissected scarp of the plateau country in the northeast, and joins the Gila a few miles west of Phœnix, on its way to the Colorado at Yuma, in the southwestern corner of Arizona.

From Phœnix we make an excursion in automobiles about seventy miles eastward to the Roosevelt dam on Salt river, one of the greatest engineering works of the Reclamation service; there we spend the night and return the next day. Our ride at first takes us through the irrigated gardens and fields near the city; then out upon the desert. We soon pass between two isolated mountains, known as Tempe and Bell buttes, which appear to be the unconcealed summits of ranges, the lower slopes of which are buried in the heavy accumulation of detritus, a drill hole near Mesa went down 1305 feet, or 80 feet below sea level, without reaching bed rock. Groves of giant cactus are seen hereabouts. We go on about 25 miles, obliquely ascend-

ing one of the long detrital slopes or "wash," so characteristic of piedmont desert topography; the detritus is coarse and its fall is about 100 feet to a mile near the mountain base; the detritus is finer and the fall is reduced to 30 or 20 feet to a mile, ten or twelve miles from the mountains.

The mountains are entered by an embayment in which stands the village of Goldfield; Superstition range rises to the south, with strikingly irregular forms. The mountains, composed in part of great masses of lava, are crossed to the northeast by a well-made road, used in the construction of the Roosevelt dam; its slanting location on a dissected fault scarp is a scenic feature of the trip. On approaching Roosevelt, we pass over the edge of a great fault block, consisting of granite overlaid by sedimentary strata; the same rock series occurs in the rim of the Plateau province to the northeast. As seen from the lower ground, the dissected plateau rim is called the Mogollon range. The reservoir occupies the depression formed by the tilting of the fault block down from the plateau; the dam is built across the gorge that has been eroded by Salt river through the upturned edge of the tilted block; an excellent foundation was secured for the dam, as bed rock was discovered only a little below the low-water channel.

After returning to Phœnix in the early afternoon of October 5 take train northward, ascend to the plateau country in the night, and run eastward on our return journey.

Forty-sixth and seventh Days, Sunday and Monday, October 6 and 7

EASTWARD ACROSS THE PLATEAUS AND PLAINS

The morning carries us up the broad valley of the Little Colorado, which we descended on October 1; in the afternoon we see part of the stretch which we passed in the night on our way

west; a stop on the Nutria monocline will probably be made at this time. During the night we cross the Rio Grande, round the southern end of the Rocky mountains, follow their eastern base past Trinidad, and run out on the Great plains. The following day we run down the flood plain of the Arkansas valley below La Junta, through southeastern Colorado and southwestern Kansas. Our view is rather narrowly limited by the bluffs of the valley side; the aridity of the uplands leaves them almost uninhabited; irrigating canals are seen contouring the bluffs, but the small volume of the Arkansas, after nearly all of its water has been taken in the dry season for irrigation farther upstream, leaves parts of the valley floor hereabout uncultivated. At Las Animas, Purgatoire river enters from the dissected mesas in the southwest, some of them being part of the lava-covered district that is associated with the flows of Raton mesa.

On nearing Hartland, Kansas, sand dunes become abundant on the plains south of the river, and so continue past Garden, while the bluffs of the upland margin approach the river on the north; many undrained basins, holding wet-weather pools, occur among the dunes south of Cimarron; near Dodge the dunes are less abundant. We turn across the low uplands to avoid a southward bend of the river, then cross it at Kinsley and traverse a broad plain to avoid the "great bend" of the river to the north, crossing the river again at Hutchinson, and there turning from the Arkansas river eastward and northeastward across the broad interfluve between this river and the Kansas, which is reached at Topeka. The interfluve is faintly marked by low, gentle, ragged, east-facing escarpments, and abundantly dissected by shallow valleys, usually of insequent habit. From Topeka we run down the valley of Kansas river, its flood plain being inclosed by dissected bluffs on either side; in the evening we reach Kansas city, at the confluence of the river of the same

name with the Missouri; the larger part of the city is in the state of Missouri, east of the confluence; a smaller part is in the state of Kansas between the two rivers.

Forty-eighth Day, Monday, October 8

IN ST. LOUIS

We have crossed during the night the maturely dissected uplands of Missouri, north of the Ozark plateau which occupies the southern part of the state; the morning finds us approaching St. Louis, where we spend the day. Late in the evening, we take train for Memphis, Tenn.

Forty-ninth Day, Wednesday, October 9

FROM MEMPHIS, TENN., TO HELENA, ARK.

The night journey from St. Louis has brought us over the northernmost part of the Mississippi embayment of the Gulf coastal plain, a maturely dissected district of moderate relief, and in the early forenoon we reach a point where the Mississippi for the last time in a long distance swings against the bluffs on the eastern side of its flood plain; there the city of Memphis occupies an advantageous position; there the last one of many railroad bridges crosses the great river. The river then swings away from the eastern bluffs, and does not return to them for nearly 200 miles farther down its broad flood plain; at that point the city of Vicksburg is located; no large city is found on the east bank of the river between Memphis and Vicksburg. At about a quarter of the distance between these two cities the Mississippi makes its only swing against the bluffs on the western side of its flood plain, and there lies Helena, Arkansas, the only city of importance on the west bank of the river between St. Louis and the Gulf.

After a brief sight of Memphis, with special attention to the shipment of cotton on the levees, we board a steamboat for a seven-hour trip down the river to Helena. The chief features deserving attention are: Two old cut-off meanders, one known as Horn lake, about 12 miles below Memphis, the other as Beaverdam lake, about 15 miles above Helena, both on the east side of the river; the original connecting channels are now silted up, and the lakes are concealed by tree growth on the flood plains. A pronounced meander, known as Horseshoe bend, turns to the west, near the middle of our trip; a recent cut-off at Council bend took place in 1874. The course of the river here is relatively simple, as contrasted with its well-developed meanders for a distance below Helena. The tendency of the meanders to enlarge their curves is shown by the erosion on the outer bank and deposition on the inner bank; and their tendency to shift their position down valley is shown by the continuation of erosion and deposition beyond the end of the curves on which they began. The course of the deep-water channel always lies near the outer side of the pronounced meanders; hence steamboats, in passing from one curve to the next, must "cross over" at the intermediate point or tangent of inflexion; it is chiefly at these "crossings" that the navigation of the river is difficult. The absence of entering tributaries is noteworthy; the small streams on the flood plain follow its slope, and hence run obliquely away from the main river; the St. Francis on the west is taken in above Helena when the river swings over near the western bluffs; the Yazoo on the east is similarly taken in above Vicksburg. The dikes or "levees," sometimes near the river bank, sometimes half a mile or more away, have greatly restricted the spread of floods, but the levee system is not yet complete enough to prevent all floods; in 1897, when the levees were

less extended than now, 13,000 square miles, or about two fifths of the entire flood plain, were overflowed, and damage was done to the extent of $15,000,000.

From Helena, we ferry across to Trotters point on the east bank, and there find our train, which then carries us eastward across the whole breadth of the flood plain, there known as the Yazoo basin. A large part of the plain is forested; the product of lumber from this district has greatly increased in recent years. Near Greenwood, in the early evening, we leave the flood plain for the upland of the coastal plain, across which we continue our eastward route through the night.

Fiftieth Day, Thursday, October 10

BIRMINGHAM, ALA., TO CHATTANOOGA, TENN.

We cross in the early morning the maturely dissected Appalachian plateau near its southern disappearance under the overlapping Gulf coastal plain. The valleys of the larger rivers have a meandering habit; they have southward discharge to the Gulf of Mexico; our route is eastward, hence we frequently pass over cols from valley to valley. Suddenly the strata, heretofore horizontal, turn upwards, and we pass from the plateau to the folded Appalachian belt, with well-defined northeast-southwest trend in its subsequent ridges and valleys.

In an open valley, close to the border of the plateau which supplies coal and in the folded belt which supplies iron ore, lies the active city of Birmingham, noted for its iron furnaces; here we stop for a few morning hours. About noon we take train again, and follow the valleys of the folded belt northeastward, crossing the northwestern corner of Georgia on the way to Chattanooga, just across the southern border of Tennessee. The leading characteristic of all this distance is the systematic align-

ment of the ridges which follow the resistant strata, and the perfect adjustment of the valleys to the belts of weak strata. The contrast between the map of the Springville quadrangle, surveyed in 1887 with 100-foot contours, and the Fort Payne sheet, surveyed ten years later with 50-foot contours, illustrates the great improvement in our newer topographical sheets. About midway, a broad synclinal mass, known as Lookout mountain, occupies part of the folded belt; it is bordered on the west by a long anticlinal valley; west of that is a still broader mass, known as Raccoon mountain in its southwestern part, and as Walden ridge in its northeastern part; it is separated from the main body of the plateau on the northwest by the long, narrow Sequatchie valley, of anticlinal structure and remarkably straight course. Lookout mountain terminates in a point to the northeast, because its synclinal axis rises in that direction; at its foot on the Tennessee river lies Chattanooga, where we arrive in the late afternoon and spend the night.

Fifty-first Day, Friday, October 11

CHATTANOOGA, TENN., PAST ASHEVILLE, N.C.

We ascend the northern synclinal point of Lookout mountain in the early morning; it was the site of a battle in the War of the Rebellion, fifty years ago; the Great Appalachian valley lies southeast of us; it is interrupted by low ridges; beyond it rise the subdued mountains of the older Appalachian belt in northern Georgia. The Tennessee river comes toward us from the northeast, and after describing a fine meander, known as Moccasin bend, at the foot of the mountain, it turns northwest and enters a meandering transverse gorge, by which it passes through the next broad synclinal mass, separating the part known

as Walden ridge from that known as Raccoon mountain; thus the river reaches Sequatchie valley, along which it flows again to the southwest, until another abrupt turn to the northwest takes it into the plateau, which it crosses to the Ohio and Mississippi. The origin of this river course has excited much discussion.

After descending from Lookout mountain, our train carries us several hours northeastward through that part of the Great Appalachian valley, known as the Valley of East Tennessee. The Appalachian trend of many low ridges is always noticeable, but in the broader spaces between them, the uplands are often dissected by insequent streams, while the larger rivers have pronouncedly meandering courses, as if they had learned to meander on broad, flat lowlands before the last uplift of the region, and had persisted in this habit after uplift; thus carrying a senile behavior from the late stages of the preceding cycle into the early stages of the present cycle. We cross the meandering Tennessee at Loudon; after passing Knoxville, where the Tennessee is formed by the union of the French Broad and Holston rivers, we follow up the latter, and, on crossing its incised meandering course, follow a broad valley to Morristown. Here we turn southeastward, and run across the grain of the country; we cross the French Broad and follow up its left bank, thus reaching the outlying ridges that flank the older Appalachians, and then entering the mountainous belt in the district of its strongest development in North Carolina. The river gorge not infrequently has precipitous sides beneath the graded slopes of the subdued hills and mountains, thus suggesting that an early stage of the present cycle follows a more advanced stage of the preceding cycle. This suggestion is soon confirmed, for after crossing to the right bank at Hot Springs, we enter the Asheville basin, an open space within the mountains; here the hills and uplands

have a nearly equal height, independent of rock structure; but the river is in a narrow valley below the upland level. The basin is presumably composed of weaker rocks than the surrounding mountains. The river is crossed twice again, the second time at Asheville, a noted mountain resort, where we stop for a noon visit.

In the afternoon we resume our journey, turning eastward up the Swannanoa; its gorge decreases in depth, and the stream is soon seen flowing in the broad-floored valley of the earlier cycle, not yet trenched in this headwater district. Mt. Mitchell, 6711 feet, the highest of the Appalachians, rises about ten miles north of our route, but it is hidden by lower summits. At Swannanoa gap (2522 feet), we begin a rapid and circuitous descent, passing from Mississippi to Atlantic drainage; the valley of the Catawba, into which we run down, has hereabouts an altitude of 1500 feet. The deeply incised headwater valleys of this and other Atlantic rivers are seen to dissect a scarp of strong relief, when viewed from farther down the main valley floors, and this scarp was named the Blue ridge by those who approached it from the southeast; but from the other side it presents no well-defined relief, as its highland crest is overlooked by the mountains which rise still higher.

We follow the Catawba through an open country, with spurs of the Blue ridge on the northwest, and isolated mountain groups on the southeast; the river is incised beneath the upland level upon which the railroad is laid after we pass Morganton; this is the begining of the piedmont belt, an important feature of the older Appalachians in the Southern States; it is an uplifted and dissected peneplain; the mountains that rise above it are monadnocks which still survive from the former cycle. We follow the piedmont belt northeastward through the night.

Fifty-second Day, Saturday, October 12

LYNCHBURG, VA., TO WASHINGTON, D.C.

The morning finds us still on the piedmont belt; we cross the James river at Lynchburg, its valley being moderately incised beneath the uplands. We continue northeastward, and approach outliers of the Blue ridge highland, among which we continue to Charlottesville, where we stop over noon to visit the University of Virginia. In the afternoon we go on northeastward, soon leaving the higher hills and passing insensibly from the crystalline rocks of the piedmont belt to the nearly horizontal strata of the Atlantic coastal plain; a single peneplain truncated both these structures, and the peneplain is now uplifted and submaturely or maturely dissected. We cross the Potomac, here broadened by slight drowning, and enter Washington, where we spend four days, October 13 to 16.

Final Days, Sunday to Friday, October 13 to 18

IN WASHINGTON AND NEW YORK

During our stay in Washington we shall visit a number of governmental bureaus, the work of which bears more or less directly on geography; and we shall make an excursion to the Falls of the Potomac at the head of a gorge, where the river passes from the resistant crystalline rocks of the piedmont belt to the weaker strata of the coastal plain.

In the evening of Wednesday, October 16, we leave Washington for New York, where two days will be devoted to meetings, and on Friday evening, October 18, the Excursion will disband.

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